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THE
PRACTICE
OF
PHYSIC.

Founded on Principles in
PHYSIOLOGY and PATHOLOGY
Hitherto unapplied in
PHYSICAL ENQUIRIES.

By JOHN SHEBBEARE, M. D.
Reg. Acad. Scient. Paris. Soc.

*Nos qui sequimur probabilia, nec ultra id quod veri simile
occurrerit progredi possumus, et refellere sine pertinacia,
et refelli sine iracundia parati sumus.*

CICERO.

IN TWO VOLUMES.

VOL. I.

L O N D O N :

Printed for J. HODGES, near London-Bridge.

MDCCLV.

To the RIGHT. HONOURABLE the

Earl of HOLDERNESSE,

One of his Majesty's principal
Secretaries of State, &c.

My LORD,

THOUGH it may appear something singular, at this time, that I should take the liberty of addressing the following sheets to your patronage ; yet, I hope, a reasonable excuse may be offered to your Lordship, when I assure you, that it is not to the minister that this sues to be accepted ; it is, my Lord, to those cha-

iv DEDICATION.

raacteristics of true nobility that kings can neither give nor annihilate, which are known so eminently to distinguish your Lordship.

It may appear, perhaps, too presuming in me to say this, since the opportunity which I have had of being known to your Lordship will scarce be acknowledged sufficient for such a declaration, unmixed with all tincture of flattery ; yet, my Lord, it is a just remark, that when the mind is truly impregnated with exalted virtues, they discover themselves by their emanating power, like diamonds by their superior lustre, the first moment they are beheld, and leave no doubt of their being genuine in the mind of the spectators. The truth of this observation, with
respect

DEDICATION. v

respect to your Lordship, is verified by the universal voice of your country.

Yet, my Lord, when I except the high office you bear, from sharing any part in the motive to this address; it is not because I pretend to judge, much less to condemn, your administration, and though I may be the first author who has ever divided the power from the patron, in an epistle which seeks protection and patronage for his productions; I rather chuse, my Lord, to address these qualifications, which are innate and immortal, than honours which may be transient and temporary; those that descend from heaven, and not from men, though monarchs; that understanding and that heart which have been so eminently and amiably

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vi DEDICATION.

exerted in distinguishing and remunerating genius and learning, unpolluted with those depreciating considerations which are found in the favourites of too many other great men.

It is, my Lord, your peculiar honour, as far as I am acquainted, to be the sole protector of men of genius, in this island; this alone would be a reasonable plea for my addressing this essay to your Lordship: but I have yet another motive; your peculiar politeness to me; and though I am by no means pleased with the occasion that afforded me the opportunity, yet I cannot regret it, since it gave me the happiness of observing what I shall ever remember with the greatest esteem.

The

DEDICATION. vii

The subject, my Lord, which I have taken the liberty to place beneath your protection, regards the welfare of all mankind ; it has this in its favour, at least, that it is different from all that has hitherto been said in physical enquiries ; and I flatter myself it contains some principles on which a more rational and permanent practice of physic may be established than has hitherto been known. This consideration alone, tho' it must want the entertainment which is found in many literary productions, will, I hope, render it acceptable to your Lordship, who have ever preferred the public good to private pleasure.

The present situation in which I am, with respect to you alone,
pro-

viii DEDICATION.

prohibits me from all power of asking permission to dedicate these sheets to your Lordship ; notwithstanding which, my Lord, I could not be at ease and satisfied, without this public declaration, how truly sensible I am of your polite behaviour to me. Though I am seldom strongly touched with the sense of injury, I would ever be influenced by the actions of politeness ; and tho' I may seldom resent the first, I never can forget the latter : and I hope I shall ever prefer the sense of gratitude to all other considerations. I am,

May it please your Lordship,
your most obedient

and most humble Servant,

John Shebbeare.

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C H A P. I.

*Of Theory in the Knowledge and
Practice of Physic.*

IN all the following account which I am about to give of vital heat and motion, voluntary and involuntary in the animal nature, there appears to me to be no one conclusion which is not fairly drawn from experiments accurately made ; not by myself alone, for too often men make experiments in consequence of some hypothesis already adopted, and not with design to form a system on experiments made without prejudice ; their minds having already taken a certain bias and propensity to some favourite manner of thinking, very often compel those experiments to speak what they imagine, and, by this they are perverted in their researches

from the true paths of discovery, and wander into endless error.

Perhaps the person the best adapted by nature, for the making physical experiments, is the least fitted to draw conclusions of consequence from them. There is required, and in general there attends a minuteness and exactness in the experimenter, which should not enter too much into the composition of the person who collects and applies the result arising from such enquiries.

The first is ever discovering little differences, contriving methods of examining objects in ten thousand various fashions, and distinguishing one thing from another by all possible minutiae.

The person who applies those experiments to the supporting or explaining any farther phenomena in nature, should be one who sees many things in one view, and comprehends the result of many effects springing from the same cause, and who overlooks the trifling differences arising from accidents of time and place.

The first of these beholds all nature as particles of dust, disunited from, and uninfluenced by one another, each a world
of

of its own, with properties and qualities distinct and peculiar to itself; the second sees all nature united, as actuated and moving upon one common principle, and all the parts conspiring to form a whole.

The experimenter is too apt to despise all systems, because he really has not extent of capacity and genius, to see and embrace the idea of many consequences from one principle; and thence considering the author as a visionary in philosophy, combining incongruities, and forming new worlds of his own, he continually makes new links, without ever forming them into a chain.

On the contrary, the systematic contemns the limited conceptions of the experimenter; he beholds him like a worm, that creeping from one mole-hill to another, and fancying each to be a distinct world, does not see the common basis which unites and supports them all; and thus this philosopher fails in the combining his system, from inattention and contempt of experimental enquiries, where too much neglecting what experiments have produced, his building tumbles into ruin, through want of those pegs which,

though little, are yet necessary to hold the whole together.

Whoever then shall form a system upon the experiments and discoveries of others, will more probably succeed in his attempt, and be less liable to be warped by his own imagination, than the philosopher who shall proceed from the beginning to the end, on his own proper researches; yet this is absolutely necessary, that he repeat those experiments on which he builds his system, to decide of their truth or falsehood; for either vanity, neglect, want of dexterity, or credulity in the accounts of other men, has led many a writer into errors very fatal to those who have credited them, and no man more than the professor Boerhaave.

In forming systems in this manner, it is as in the abstruse mathematics, and the knowledge of the laws of the heavenly bodies. An astronomer may perfectly well observe the motion of all the planets, and yet never calculate the result of those observations, whilst a mathematician of sagacity, who never looked through a telescope, shall first conceive, and then deduce, by various
combi-

combinations of numbers, what the observer would never have produced from the force of his own proper talents ; and thus each is reciprocally obliged to the other.

It is in the understandings of men, as it is in their bodies ; the first has a certain power as the latter has a certain strength, beyond which it cannot pass ; one man shall carry off in one burthen what another has brought together in six, and with more ease to himself.

Notwithstanding the favourable appearance which the following manner of accounting for vital heat, and vital motion, may have in my eyes, I am persuaded that the same prejudice attends every production of the head, which operates in favour of our children. It is another self in each instance, and all this truth to me, and my manner of thinking, may appear absolute falsehood to others ; however that may be, all I request is, not to be condemned unheard, or by improper judges ; let what is here said be considered with some attention by those who can decide, and let the others be well acquainted with the animal formation and œconomy, with the powers and properties of fire, before

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they

they determine, and I willingly stand to their award.

But it often happens, that those who do not understand the first rudiments of arithmetic, shall strenuously insist that there is not the least utility or truth in applying mathematical knowledge to the discovering the laws of the animal œconomy, or of curing diseases; and others, who never saw one process in chemistry, assert that every experiment made on the solids and fluids of animal bodies, by heat in different degrees, and the mixture of various substances, is entirely void of all foundation in truth; and that common sense is the best guide in the knowledge of diseases and their cures. But methinks, common sense would say also, that whoever decided of their inutility, should first have studied those arts.

There are others who leave all to nature, and give sly insinuations, that medicine has but little in it, and that the whole secret consists in helping her at a dead lift. This last indeed may be very true; but to assist her effectually, it ought first to be known what she is doing, or otherwise we may
overfet,

overfet, instead of proping her, and be her destroyer by mistaken friendship.

Besides these, there are the advocates of experience, who look with pity upon every thing but length of years and grey hairs : in one thing however, there is an universal agreement amongst all the different kinds which have been mentioned ; and that is, to condemn all knowledge which must cost pains, and require application in the obtaining, and to stigmatize every thing which they do not understand with the brand of useless theory.

But let it be seen what common sense, as it is understood by them, would effect in a similar case ; would it inform a man who had never learnt or studied the principles and practice of making a watch, the best manner of setting it right when out of order ? Would it persuade him to send it to my lord -----, though he has as much genius and common sense as any man living, so readily as to Mr. Mudge in Fleet-street, who is but the best watch-maker in England ? I fancy not.

Yet, in truth, there is a common sense in medicine and physic, as there is in mecha-

8. *Of Theory in the Knowledge*

nics and in general life, which rises from the knowledge of statics, hydrostatics, chemistry medicinal and experimental, anatomy, physiology, and all the other parts of natural philosophy in general; together with the history, observation, and attention to diseases. This, like that in mechanics, which springs from the knowledge of the powers and properties of elasticity, gravitation, number and combination of wheels, or of life in general, founded on observations and experience on the different faculties and properties of mankind, will form a common sense in physic, but very different from what is commonly conceived, and which, it is extremely evident, does not differ from theory but in the word, and consequently, without this previous theory, there can be no pretension to the qualification of common sense in physic. It must be allowed also, notwithstanding all that has been said in favour of theory, that those physicians who have attached themselves entirely to one manner of accounting for disorders, and prescribing a cure for them, in consequence of it, have equally erred by running into the opposite extreme, from those who slight all theory entirely,

entirely, and by endeavouring to account for and subdue all the operations of nature to one property of it.

The mathematician will reduce to demonstration, on mathematical principles, the cause of every disease, and the method of every cure; he will calculate the projectile force of the heart, the velocity of the blood, and their effects on vessels of different shapes and sizes in the animal body, and apply those laws, founded on the properties of fluids in motion, and tubes of different shapes and sizes, which are measureable, to those in human nature which are not, and reject all accounts which do not carry the face of demonstration, without considering that poison and nutrimental fluids, water, and wine, are under the same hydraulic laws in the circulation, and yet their effects extremely unlike on the animal frame.

On the other hand, the chemist and natural philosopher, pursuing their enquiries on the different effects of the degrees of heat on the same matter, and of the effects of different mixtures with the blood, of the greater or less proportions of the crassamentum and serum, the stronger and weaker adhesion

hesion of the particles of the latter to one another ; and finding those effects have no necessary connection with the known laws of motion, and shape of the vessels in animal bodies, they condemn the mathematician and his hypothesis, and establish a new system, upon their enquiries and manner of philosophy. In reality, each of these two philosophers has right and wrong on his side; the mathematician pushes his hypothesis, and certainty too far, in expecting that a demonstration of the cause and cure of disorders must infallibly result from his calculation ; the calculation may indeed be true, but it is not applicable in that place, nor to those uses in nature.

Notwithstanding this imperfection in the nature of mathematical calculations thus applied, a physician would act extremely wrong who did not attend to this very manner of considering disorders arising from what is called plenitude and inflammation. Though the force of fluids circulating in animal tubes, cannot be exactly known by any calculation, yet it is surely discoverable, that a greater projectile force, or greater quantity of fluids, will more probably cause a rupture of the blood-

blood-vessels and a hæmorrhage, than a less force and less fluid, and consequently suggest the lessening that impetus and quantity of blood in the vessels.

On the other hand, the mathematician who despises the experimental and chemical philosophy, because effects within and without the body, under or beyond the laws of circulation, are by no means exactly similar in the same experiments made on the same substances, would be extremely culpable in asserting there was no degree of truth in, nor advantage to be drawn from, this manner of examining the animal nature, and in explaining the cause and cure of diseases.

In fact, each of them has a certain degree of truth, though not an absolute one, in what he advances, and errs only when he denies a truth to the other: there are diseases which arise from the encrease or decrease of the quantities of healthy fluids, which are curable by the diminution or augmentation of those fluids only, and where the mathematical way of accounting is applicable both to the cause and cure of them: there are others where the fluids are tainted with some contagion, and where all mathematical

mathematical reasoning and practice inferr'd from it, would be pernicious to the greatest degree; to know which is one or the other, is the province of the physician, and as he can distinguish, will be his success in the practice of that art which he professes; the same holds true in all the different ways of considering the animal œconomy, and the irregularities to which it is liable.

To assist nature therefore, seems impracticable, without knowing in what vitality and vital motion consists, unless it be by hazard, a too precarious principle to proceed upon, with any degree of safety and self-satisfaction; and when this may be discover'd, the various methods by which she can be disorder'd, and all the vital faculties extinguish'd, should be known, or it boots but little to pretend to assist her in her operations; and after all, if these should be happily brought to light, there yet remains a third part of physical science, which consists in the knowing of the operation of those remedies which are applied to her relief on the contents of the animal body.

If these things are actually true, of what use can experience be to any physician who
has

has never previously studied those parts of his profession, and who despises the knowledge of them? All that can be drawn from it is the seeing more people expire, and the better acquaintance with those symptoms which appear in different disorders; but this is but acquaintance with the face of disease, and not the internal source; it shall assist him in telling the danger the patient is in, but not the method of extricating him from it. How would the observation of clocks going faster in cold weather, and slower in hot, contribute to the remedying it, without knowing that all metals dilate and contract by heat and cold; and that the pendulum vibrates in more or less time, in proportion to its length: this being known, the alteration is easily made by any man, but impossible before that time but by chance. Yet experience has its use also; the being acquainting with the various symptoms of disorders, and the truly distinguishing one from the other, is only obtained by seeing numbers of people ill at the same time, of the same disease in hospitals, and observing with accuracy and impartiality, if the practice consequent of our theory, is truly

truly beneficial and well founded ; thus the union of theory and practice must combine to form a good physical knowledge ; it is possible the first indeed, without practice, that is theory, may lead directly to health, from its being establish'd in truth in its beginning, the last can be but right by chance ; and as there is but one right way, and innumerable wrong, the assistance expected from casual causes, will weigh little in the judgment of men of sense, and assist less in curing the diseased.

After all I have said, it does not escape my remembrance, that physicians in general agree, that the animal nature and œconomy has not yet been sufficiently explained by physiologists, to decide in what vitality consists, and those motions in consequence of it ; that hitherto the explication of the powers of medicines on the animal solids and fluids have been rather bewildering the student than instructing him ; and thence they infer, that little is to be gathered or expected from that quarter, and in general condemn all attempts to physiological researches. But this indeed is to give authority to ignorance, to level all talents to one degree,

degree, and exile every farther attempt to the encrease of knowledge. There are continual instances of new discoveries, which were unhop'd and unimagined before; and very often, tho' the whole object propos'd in the research is not obtained, yet ample rewards to the enquirer, at least to mankind, in a different light from the first intention have been the fate of such enquiries; even the search of the philosopher's stone, the most visionary of all pursuits, has rewarded the pains of the alchemist, sometimes in leading to discoveries which are extremely useful.

It will be allow'd however, that the object which is attempted to be discover'd in the following sheets, is at least worthy all the pains and application in the human powers; and that, tho' there be much less success attend it than is usually expected by the person engag'd in such pursuits, yet there is some merit in endeavouring to save, tho' we fail in the attempt.

At the same time, I am not ignorant, what opposition all new discoveries must meet with from many prevalent propensities in human nature. The minds of men
grown

grown old in any way of thinking, are like heavy bodies on the surface of the earth, which by long lying have sunk into the ground, and form'd to themselves a bed, from which they cannot be easily removed, even with very great strength; there is a kind of *vis inertiae* of soul as well as body; or novelty, tho' it be true and convincing to them, may yet be displeasing, because it puts them in mind of their having been wrong all their lives long; with those of younger years there are other reasons, which weigh and effect the same purpose.

Besides this, it is well known, that very important discoveries, like rich mines, have lain long unattended to, slighted or misunderstood, and yet after that universally adopted and brought into philosophy and use.

Notwithstanding those discouraging considerations, the following sheets are publish'd to the world, from conviction of the truth which they contain; and this with every honest man ought to outweigh every timidity of its reception, and give him courage to offer, at all risque, what presumes from its nature the probability of being so useful to mankind, tho' perhaps in going
contrary

contrary to the sentiments of all men hitherto known, and offering ourselves to the calumny of many, it requires as much resolution as in opposing ourselves to any other danger whatsoever.

Thus it appears to me impossible, that any rational foundation whatsoever for the practice of physic, can be laid without previous theory, and that hitherto the application of experimental knowledge has not been satisfactorily exerted to the explaining in what vitality and vital motion consist.

The irregularities and mischiefs the animal machine is open to from the influences of various bodies, and the qualities in medicine by which those evils may be opposed, are still involved in great obscurity.

To throw some new light on these subjects, is the design of the following essay, in which, with respect to the anatomical part, I do not pretend to have made any discovery of new parts in the human body, but to have assigned a new use, and a new manner of operating to many; for this reason, amongst others, all tedious descriptions of the parts are omitted, those being already sufficiently known, and exactly

described; and what is here said will be sufficient to convey my meaning to those who have studied and understand anatomy, and to put them upon the seat of judging of its truth and falsehood; and all that can be said will never place those in that situation who neither have or will study at all.

It appear'd to me also, that the pursuit of discovering the reality of fire and its properties, by electrical experiments, had been push'd sufficiently to be applicable to some general utility; and tho' all which has hitherto been found, has remain'd still unapplied to the explaining any phænomenon of much consequence to mankind, yet that there are experiments already made, which may fully furnish proofs of the truth of what is to follow in this essay, relative to vital heat and motion.

However this may prove in the event, contrary to my imagination, and there should yet remain physicians attach'd to the belief of animal spirits, it may be remark'd, that even under that supposition, and in granting all that anatomists who have thought in that manner require to support their hypothesis, yet even then they must have err'd

in their accounts of the manner in which the vital and other animal motions are perform'd, in asserting, that the systole of the heart could have been produced by the influx of animal spirits into its fibres; and in adopting animal spirits as the spring of all motion, even then the mechanism and action must be as it is here explain'd.

But why, in accounting for the phenomena of the animal being, should we fly to a resource of explaining them, which is in itself altogether visionary and undiscoverable by any experiment, and at the same time desert those powers which are obvious to almost all our senses?

In the following way of explaining the operations of animal nature, vital heat and vital motion have one and the same cause, the latter depending on the same principle applied to variously form'd parts; and thus it appears to be in common observation, whatever lessens or encreases the vital heat beyond its due degree of health, is so far destructive of all animal motion, and the reasons why cessation of all motion arises from too much heat, as in the most ardent fevers, and from too much cold, as being

exposed to it, or, at the decline of diseases and old age, are to be assign'd from this way of explaining the vital powers.

Through the whole account, I know of nothing ask'd or supposed, which physiologists have not already agreed to exist in the formation of an animal; we require no more than the bare existence of objects discoverable by our senses, and proved by experiments, to affect the organs of our bodies in the manner we design to support and explain all that is intended to be done in this essay.

I am sensible, it is natural to mankind to urge their manner of thinking and explaining things beyond what it will fairly bear, and make all nature submit to their imperial hypothesis; and which perhaps, takes its foundation from one single property of matter. This, I hope, will not be objected to the following manner of accounting for what is proposed in this essay, where, endeavouring to explain the cause of diseases, and to assign each according to its proper genus, and thence deducing all the different species springing from the same source; it is but in imitation of nature, who under the
class

class of moss and other vegetables, tho' great numbers are unlike enough to be distinguish'd from one another, yet resemble each other so much, as to be ranged under one common head, known by the same name and appearances.

The assigning one particular cause as universally productive of diseases, is too much for that variety which we see in nature, and the giving every disease distinguish'd by a different name, a separate and distinct cause, is too various for that simplicity which we discover in the ultimate of most phenomena.

There is one advantage which seems to flow from this account which is to follow, that is, the disorders which have been distinguished by the word nervous, and hitherto so little to be explain'd from any principle in physiology, will now receive an explication which may prove satisfactory in its manner, and serviceable in its application; and the different causes of symptoms very much resembling one another, may be distinguish'd, and prevent the fatal effects of that indiscriminate practice, which is too much follow'd in nervous diseases.

The true reason of those difficulties which attend the cure of apoplexies, palsies, epilepsies, and many nervous complaints, and the sometimes impossibility of curing some of them, will appear evidently, and lead to a safer path of treatment, as well as other disorders in general, will receive a foundation in assigning their causes, whereon a more safe and satisfying method of cure may be built by the physician.

What inclines me the more to say this is, that the practice which has hitherto proved the most successful, reciprocally supports, and is supported by this theory. And that, tho' the account of the manner in which medicines operate, is very different from what has been hitherto believed, or ascribed to them, yet perhaps, 'tis the only one which can afford any probable explanation of their operation, and of those sudden effects which various poisons produce on the animal body, as well as of those distempers which are here attempted to be deduced from the poisons of an inferior degree; as also of the sudden operation and influence of fumes and effluvia, both noxious and refreshing, which are found so instantaneously

taneously to take effect on our bodily powers.

If this be the event of what is to be found in the following pages, there will be at length an end of that fluctuating practice which at sometimes has been as cold as the snows of Zembla, and at others, as hot as the torrid zone; as if men, like salamanders, could live in nothing but eternal fire.

This unstable way of practice has been an everlasting reproach to physic and physicians; the uncertainty which rises from want of principle in the prescriber, the superstition so natural to minds when the body is diseased, have engender'd that swarm of quacks and quack medicines, which are not a little destructive to human nature, and secretly carry off millions in a century. No one complains of the death of a friend, when that person has died by his following the taking quack medicines; he was his own executioner, a kind of *felo de se*, or there is no one to blame, and all passes on in silence; thus hundreds die by a medicine by which one may recover. Every news-paper swarms with advertisements of the excellence

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lence and superior powers of that medicine which has kill'd a hundred of his fellow-subjects, whilst it was curing him ; and in gratitude he ought to speak well of it ; it was a bridge over which he past, tho' hundreds besides dropt into the river and were lost. We are more obliged to the tyger, if he spares us, because 'tis his nature to devour, than to the angel or superior being who shall warn us from the approaching evil, because it is his nature to save, tho' it favour strongly of ingratitude in us.

I am fully satisfied also, that those principles upon which the vital heat and animal motions are explain'd, may be carried much farther than has been done in the following sheets ; yet this will answer my expectations, if by the unfinish'd design of the following essay, more able physicians may be induc'd to turn their thoughts upon these subjects in this light.

Let what is here said, if it prove true, be consider'd as the first sketch of a painter, which tho' it want correctness of drawing, may yet have some merit in its invention and design : if it be received in this view, some better hand may execute what remains ;
if

if not, it will of course sink into oblivion, with many other preceding attempts of the like nature, if it escapes the flames and first rage of the reader.

Thro' all the following sheets I have quoted but seldom the authors who have furnish'd me with many a useful remark and experiment, unless the experiment has not yet been publish'd; in which case, it was an obligation on me to mention the person who had invented it. At the same time, this omission does not arise from neglect, contempt, desire of concealment, nor ingratitude; but thro' mere inclination, to make this essay as short as possible. There are great obligations which I owe to celebrated authors, both ancient and modern; and whatever shall be found in this work belonging to them, I desire to have it replaced, and attributed to their account; at the same time also, greater acknowledgement, perhaps, is due to those who err in their accounts than is generally owned; they serve like the shipwrecks of sailors, on dangerous ill-discover'd coasts, and hidden rocks, to furnish us with better charts, and keep future adventurers from approach-
ing

26 *Of Theory in the Knowledge, &c.*

ing too near to those perils; and thus turn us partly into the right road, by showing the way of avoiding the wrong.

Yet those who have used words without ideas, and expected that mankind should be satisfied with their accounts, are in no sense entitled to the merit of the former, who have gone wrong; for not being intelligible, they are neither true nor false, and neither direct you to or from any thing, and are in truth, the writers which throw the greatest disgrace on science and theory.

As the reality of fire is yet disputed by many philosophers, it seem'd necessary to establish the truth of its existence, before any thing was concluded from its operation; and the chapter of the cause of ideas, seem'd to make part of the subject; tho' at first sight it may appear of a different nature. For these reasons, I hope to be excused the liberty of having inserted them amongst the other parts of this essay.

C H A P.

C H A P. II.

Of the reality of fire.

THE pursuit in which the philosophical world has been engaged in discovering the properties of electricity, and the various phænomena which this electric matter has afforded, analogous to those discovered in fire, have induced many philosophers to believe it no other than that element ; this has naturally awakened, with some ardour, the old dispute, whether fire in itself is really and truly a being like water, air, and earth ; or an adventitious and accessory property resulting from the intestine motion of the insensible particles of matter ? The former manner of thinking has been adopted by Homberg, Boerhaave, Lemery, and St. Gravesand, and others ; and the latter by Bacon, Descartes, Boyle, Sir Isaac Newton, and their disciples.

Perhaps Mr. Locke, in distinguishing between the reality of what he calls primary and secondary qualities, may have added some weight to this latter manner of thinking.

But

But let us examine what it is in nature which constitutes the ideas which accompany the words elementary, or real being; and this, perhaps, may let in some light upon the question.

The first and most simple way of considering nature, is under the idea of unity; this is the metaphysical consideration, in which the universe, the world, and any object, is represented as one to the faculty of reason in man; but as the human mind is not capable from its fabric of keeping one idea the same in all lights, any two succeeding minutes before it, without conceiving some difference in the object; and as the mind is also compounded of very different faculties, and as each faculty will vindicate to itself its objects, and the truth of them; the imagination necessarily succeeds to this primary way of conceiving things, and taking place, makes the first great division of the whole, as it stands to the reason, into matter and thought, which continually run parallel to each other in nature ever after.

From this way of considering things, it naturally arises, that all the variety which we find in those objects, which are offered to
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our senses, must spring from the different modifications of matter, without more truth in one than the other, and consequently every modification has an equal title to be considered as real ; because each depends on the different arrangement of the particles of that matter, which is the universal basis of them all.

This is the way, in which all the phænomena of nature must appear to the abstract and metaphysical eye, which, first through reason, beholds all nature as *one* ; and then by the imagination and senses, divides and perceives the same object, under all the different appearances which the material part of it is capable of putting on, in the different combinations and arrangements of its particles. In this manner of considering objects, fire must have an equal right and authority to the being a real existence, with water, air, and earth ; and these, and every other modification, an equal right with fire.

There is another sort of philosophers, who beginning with the objects of sense, and the examination of the properties of different bodies, have found that in those which come

under the examination of the senses, fire, earth, air, and water, have been discovered indiscriminately in all, though differently proportioned in quantity. These have concluded, from this universality of those particles entering into the composition of other bodies, that they are in themselves more elementary and real ; and all others, as secondary and accidental to the different proportions of those elementary particles, entering into the composition of their bodies.

The first manner of considering nature in beginning with unity, and thence deducing all those differences, is undoubtedly true to the reason and imagination ; and in that manner, those objects of fire, air, earth, and water, are no other than matter more generally disposed to put on those appearances, but not more real nor more elementary than those which are more seldom seen. Water in this case is more general, but not more elementary than gold ; in nature beginning with reason, there is no other truth but that of unity.

But in beginning by the senses and their objects, though the modifications of matter which make air, earth, fire, and water, are
not

not more really existing than those of brass, wood, &c. yet the senses having discovered those four bodies in the composition of all others whatsoever, and wanting some certain foundation to support the building of natural philosophy, and the last result of examining by analysis terminating in those four more general exhibitions of substance, the mind has taken those so generally disposed particles of matter for primary and elementary, and concluded the other to be less real, secondary, and accidental, without any absolute foundation in nature ; and in this way of conceiving things, those four properties, so universally found in all bodies, must force themselves upon, and be considered by the mind, as real primary and elementary beings ; and this is the truth of nature as it stands to the senses. The same manner of reasoning may be applied with equal truth to the principles which the chemists have adopted, and built their systems upon.

In both these ways of examining nature, whether you begin with it as it stands to the reason, and then dividing it, by the imagination, into all its different modifications ; or whether you begin with the most general proper-

properties, as they stand to the senses ; and thence compound them into all the variety of nature ; fire has an equal pretension to reality with air, earth, and water, because it is obvious to the senses of seeing in light, and of feeling in heat, in the same manner with all those other supposed to be real.

Notwithstanding this, it has some way happened, that the reality of fire, as an element, has been disputed, though the other three have past unattack'd ; and an intestine motion of the insensible particles of matter has been supposed the cause of fire, and heat nothing real in itself, but a property of this particular kind of motion.

But methinks, nothing seems more strange than to imagine motion can impart a property which it has not in itself. What kind of connection is there between the ideas of burning, and motion of any sort ? or how comes it to pass, that motion can account for any thing but motion ? Imagine all kinds, if you please, let them begin how they will, and take as many different directions in all their different particles as you please ; will this convey to your mind the idea of heat, light, or fire ? Had you never felt the effects
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of heat, though you had seen the intestine motions of all the particles of the globe, do you conceive these motions would have given you the idea of heat or of light.

Whence comes it then, that this motion has been assigned as the cause of heat? It seems to be from this: whatever we see immediately to precede any thing, we are extremely apt to consider as the cause of it. From thence perhaps, Bacon, Descartes, Boyle, and Sir Isaac Newton, having observed that heat followed the friction of two dry bodies upon each other, that a cord caught fire by being rubb'd against hard substances, and that a piece of iron might be beaten red hot, were inclined to imagine, that this motion was the cause which generated this heat; but a person who had never seen those experiments, and who had observed, that motion of some kind or other had been always produced in all matter upon the application of fire, would certainly have concluded, that motion was caused by fire. If then those two properties of motion and heat, suppose, had equally preceded each other, according to the observations which any one had made, the person must have suspended

his decision which was cause, and which effect; and in proportion to the inequality in the numbers of these two properties, succeeding each other, he would have determined of the truth of motion's being the cause of heat, or heat of motion.

But, on the contrary, if it should prove by examination, that motion, of some kind or other, is always the consequence of fire being applied to every kind of substance, and that heat is very often by no means the result of motion, but sometimes the opposite; the conclusion in consequence of this universality in fire of producing motion, must terminate in the reality of the existence of fire, which never fails of producing motion of some kind, in opposition to motion's being the cause of fire, which at best is but general; and especially, as motion given to fluids by the solution of salts, produces a considerable degree of cold. It would be difficult to explain the different motion which produces heat in the mixture of vitriol and water, from that which produces cold in the mixture of sal ammoniac and water. From this we ought to conclude, that fire is a real being, as it is universal and constant

stant in its productions of motion; whereas motion, at best, is but particular in its generating heat, and often contradictory.

In short, if it must be concluded, whether motion is the cause of fire, or fire the cause of all motion whatsoever, we ought to conclude on the side of fire; and perhaps it will appear at last, that even gravitation, and attraction of every kind, depend on that very element; at least, tho' experiments have not yet been made sufficient to decide in favour of that supposition clear of all doubt, yet there are many which offer reasons to believe it. However this shall be in the event, it will make no difference in the laws of attraction, as discovered by Sir Isaac Newton; those laws being still the same; whatever may be found to be the cause of them; and light or heat, though a being, and every where dispersed through the whole of things, tho' it may destroy the notion of a vacuum; yet as it affords no resistance to bodies, or at least an uniform one, which is uniformly overcome by the power of fire, it can effect nothing in the calculation of the motion of the heavenly bodies.

There remains to examine whether those properties which are consider'd by Mr. Locke as primarily, really, and essentially existing in things, are more truly so in their natures, than those which are imagined as secondary, accessory, and depending on the contexture, figure, and motion of the insensible parts of matter. According to this philosopher, size, figure, number, situation, and motion or rest of the solid body, are real and essential properties of matter; and heat, taste, odours, &c. are secondary and dependent qualities: the first are absolutely the representatives of things as they are, the second unlike their causes, and depending from contexture, size, and motion of their insensible parts. But will not a closer enquiry put all these seemingly different qualities upon the same bottom of truth? For example, let us compare size and colour together, and see whether those qualities differ or agree in the reality of their existence.

First then, the size of this book is an object of my sense of seeing, as well as the colour of it; the same organs decide of the being of the one as of the other, and thus far they are equally real objects. Again,
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the very same particles which inform my eyes of the size of this book before me, inform them also of the colour which it has. At the distance which it is from me, it appears of a certain size and certain strength of colour; and at another and another distance, it appears still less in size and less in colour: thus again, this reality of size keeping pace with all the differences in colour, can be no more absolutely real, than that of colour, which is said to be relative; for if this primary and original quality of size, has more truth of existence than the secondary and relative one of colour; whence does it arise that it is still liable to the same effects of distance with the secondary? Are not all the different shades of this colour in the book, arising from the different distance of the object, exactly corresponding with all the sizes of this book arising from these distances? how comes it that the same particles which give me the size and shape of this book should be more real in their nature than those same individual particles which give me the colour? or how comes it that two effects arising from one and the same cause, can be said to be the

one real and the other accidental? or how can the idea of colour be less truly existing in nature, like the object from whence it flows, than the size and shape, which are allowed to be representatives of their objects? when the same particles give you the idea both of one and the other quality, and the same sense is concerned in the conceiving them.

If by any means the colour of this book is changed from what it was, it must be either by adding something to it or diminishing those parts which it already has; the same addition or diminution of parts will affect the shape and size. For example, I cut off each corner, and the former shape and size are destroyed, it becomes an octogon from a square, and the colour continues the same; or I add some tincture of a different dye, and the colour is changed, and the shape continues the same: can there be any more reality in size than in colour, when each is under the same power, and one can be as arbitrarily varied as the other? for as the shape of an object may exist in every colour, so any one colour may exist under all possible shapes of the object.

But,

But, divide this object as you please, there still remains some size and some figure in every part of it, and change the colour as you will, there still remains some colour in every part of it. But size, figure, &c. remain in the object in the dark, and colour not, not to the eye: the moment that sense decides of the size and shape, it decides of the colour; and the imagination, in recalling to itself an object, the idea of a die, for example, does not recal the figure of the ivory more strongly than the white, and the spots; and in this very case both to the eye and imagination the secondary qualities, for instance, the spots and white, determine it a die, and not the figure, that only says it is a cube; the spots determine it a die, and not the number separately from the spots; for certainly number, as it stands there, owes its reality to the same cause which gives it colour, or the privation of it.

Whence has it arisen then, that figure, size, number, situation, and motion, have obtained the titles of real and original qualities, and the corresponding ideas as representatives of those very qualities in matter, when those of warmth, odour, colour, &c.

are imagined as secondary qualities, and relative to the contexture, motion, and arrangement of the insensible parts of matter? The reason of this is, that the objects of the first kind are distinguished by more than one sense, and of the second by one alone, Shape, for example, exists to the touch as well as the sight; situation and motion are also objects of the feeling, and numbers of the hearing, and of every sense, as objects succeed each other, one smell may follow another, one sound another, and one taste another; and this creates the idea of a superior reality in number, without more truth in this general idea, perceptible by all the senses, than in the single one of colour perceptible by one alone; and as those qualities are the same in all matter, whether warm or cold, sweet or disagreeably scented, of one or of all colours; and as in this sense of feeling, particularly, the object and the organs are brought in contact with each other, we are apt to conceive more reality in this sense and its objects, than in those of seeing, hearing, and their objects; and accordingly we are led to explain all the other senses by a kind of feeling; the eye feels the colours,

lours, and the ear feels the sound; but in fact, it would be as true to say, the ear smelt sound as that it feels it; every object is taken off by every sense intuitively, and all the senses are upon the same bottom of truth: as may, I hope, appear where it shall be mentioned of the uselessness of animal spirits, æther, &c.

But it seems not at all difficult to show, that number has no real truth to the eye, above that of colour, nor to the touch, or the sense of feeling, above that of sound. In speaking of numbers, I don't mean that real and abstract idea of number which is the object of reason and the metaphysician, and of which the eye takes no cognisance, but that which belongs to an object denominated one to the senses.

For example, an eye which receives the same configuration with that of a man who has drank too much, immediately sees two candles in the place of one; there are to his eyes really and distinctly two candles, and supposing this configuration to continue, the man, however sober, must conclude they are two candles really existing. The same is true with respect to motion; if the eye
takes

takes the same disposition in all its parts, which it does when objects are moving before it, all things around are in motion : thus you see the truth of the objects and their qualities do not depend on the reality of any properties in themselves, but are relative to the sense which conceives them.

Again, the same is true with respect to the sense of feeling: a marble with which children play, if felt with the fingers a-cross, is perceived as two by that person who feels it ; and the person must continue to feel and perceive it as two to that sense, whilst the fingers are in that position.

Thus it plainly appears that all the difference in objects, arises from the different configuration and disposition of the parts of our senses, and no reality in one more than the other, only as some, number, for example, is the object of all the senses, and inseparable from all matter, we are apt to give it a reality from that circumstance which we do not allow to the objects of one single sense.

But let us see whether there is any real connection between the ideas, as they arise from objects offered to one sense, and the ideas of those objects as they are offered to another,
that

that is, whether there is any connection between the idea of square or number, as it is conceived by the eye, and as it is perceived by the touch, beyond what experience gives us ; if there was, methinks, the contrary would have happened to what has been discovered, in the experiments made upon those who were born blind, and came to sight after some operation.

The person born blind had to his touch as clear and distinct an idea of a square before touching as after ; and thence, of consequence, if the idea arising from a square object, or a certain number or numbers to the eye, had been the same with that of the touch, he would have immediately distinguished this figure and number from all others ; but, on the contrary, he was obliged to feel all objects, to distinguish what he meant by square, round, &c. and to count them with his hands, to know the quantity ; and when he had once by experience seen that the object which was denominated square to the touch, had a certain and determinate figure to the sight, those two ideas in his mind were ever associated and considered as one, under a common name of square, though utterly inexplicable and

and unlike to one the other as they are conceived by the different senses. The same is true of number, and would be true in any instance of any of the two senses, where an object may be the idea of both ; and thus of consequence, an idea which is conceived differently by each sense, though connected in all the different manners of perception, by experience only, can have no more real primary and original quality in itself, above that which arises from an object, which is cognisable by one sense alone. And thus number has no truth in its real nature, superior to colour, sound, or taste.

If this was not the truth of the fact, a man, suppose, who had no other sense but that of the ear, must conclude that there was nothing real in all nature, because sound has nothing of reality in itself ; and yet this person so circumstanced, would conclude the directly opposite, that sound was the only true existence in material nature ; the same would happen in favour of odour to a person who had no other sense but that of smelling, and of taste to one who had no sense but that of tasting ; because in each instance it would be the only proof of the existence of matter to him so form'd.

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In fact, as we really are form'd with five distinct senses in nature, we as confidently and truly decide of the existence of any thing from its qualities, which are called secondary and adventitious, as from those which are named primary and real. Sugar would be less decided to be that substance, if it wanted sweetness than shape; and dissolved in water, where shape, size, and motion of the whole body have nothing to do, it is as absolutely determin'd by the palate to be sugar, as it is by the eye, when in a solid appearance.

An artificial rose which deceives the sight, is not decided a rose without the other proof of odour to the nose; and an object, however like a bell it may appear, is not consider'd as such, without sound. Does it not seem to carry a contradiction in itself, when we assert, that those secondary qualities which depend on the primary, can be more sure proofs in determining the existence and presence of any object, than those very qualities from which they are supposed to derive their very being and reality?

In the instance of different motions, what greater reality can there be in the quality of
matter's

matter's being moved from place to place, or being still, than in the intestine motion, or rest, of the insensible parts which compose the object? How is the idea which arises from the whole mass being put into motion, more true, or springing from a more real quality, than that which arises from the motion of the insensible parts of the same mass of matter? Why is the first consider'd simply as motion, by the eye, and the latter, which is avow'd to be motion also, as colour, blue, green, or any other, for example?

From this it seems to appear, that all ideas are true or false, relative to the senses they are the objects of, and not to the reality of the qualities from whence they proceed. No two eyes see exactly alike, because there are no two eyes precisely form'd alike; the result of every object offer'd to the senses of any man, is a particular truth to that person, with some difference from that of every other person, in proportion as the senses and their organs are differently form'd and disposed in the two men.

The purgative quality of manna, is, to a delicate constitution, as real and essential

a quality as figure; and whoever, after repeated experience of that property, had found it fail in that respect, would be no more induced to believe he had taken manna, without that effect, than if it had wanted figure, or any of those qualities which are esteem'd primary and original.

The power in the sun of turning wax white, is as real and original a quality as light itself; but as was said before, in the case of motion causing fire, we are extremely apt to take what precedes a thing, to be the cause of it. Thus, as we first see the rays or light of the sun, and then the effects produced by them in the wax, we are induced to consider the sun as causing those rays, and then those rays the change in the wax; whereas, in fact, the same cause exists equally true in both, and operates at the same time; but as we are obliged, by the very make of our minds, to conceive but one idea at a time, and all in succession, we thence falsely conclude the preceding to be cause and the other effect; and thus the power of whitening wax is as truly an original and primary quality in the sun, as that of creating the idea of light; take from it
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the power of effectuating the first quality of turning wax white, and at the same time you take from it the power of creating the idea of light: Now those effects, which can never be divided, must spring from the same cause : or the cause of two effects, neither of which can subsist separately, in taking it away from one of them, must be the same ; and the sole difference arises from the difference in the objects which receive this influence.

Thus then it seems to appear, that all objects are equally true, and that there is really no essential difference in nature, between those qualities which are called primary, and those which are said to be secondary ; and, of consequence, that fire, and all its degrees of heat, have in themselves the same original truth with figure, motion, and all the other properties of matter whatsoever.

The difficulty which has so long attended the acknowledging the reality and elementary existence of fire by many philosophers, arises perhaps from the implicit credit we are apt to give to all the opinions of very great men. A man of superior genius,
who

who has distinguish'd himself above the rest of his species, in new discoveries, more extensive reasoning, or more accurately investigating truth from the properties of being, naturally gains an ascendant over the minds of others, and spreads a kind of sanction on his mistakes; 'tis little less than sacrilege to examine even his conjectures, and time only, which lessens all other reverence, must wear off a little of that which we have conceived for him, before we can acquiesce in his being fallible. For that reason I have endeavour'd to establish the reality of fire, before I speak of its effects; as it seems of importance to settle the existence of those principles on which we proceed; and as it does not come to my mind, that they have hitherto been treated in this manner, I hope the time which I have taken from the reader will be forgiven me.

If Sir Isaac had consider'd fire as a real existence, and not indulged the belief of an æther; if he had pursued the disquisition of this being thro' the phænomena of electricity, it is probable that, with that marvellous sagacity, and great imagination, that power of calculating, and patience in persevering,

vering, the effects of it had been discover'd beyond what it is easy to hope it may be at present; for however extraordinary some of the effects of this electric effluvia may be, a man of Sir Isaac's genius is yet a more amazing phaenomenon in nature.

It may still remain a doubt with some, that all I have said does not amount to a proof, and as metaphysical reasoning is not in the highest esteem at present, it may be expected, that I give some experiment of its reality, and its not arising from motion: to which I shall only answer, in giving what Mr. Watſon has discovered, by putting the electric machine, and men who turn'd the wheel, and rubb'd the glaſs on electrics perſe; which is, that after the globe had thrown out a little quantity of electric fire, there was no longer any appearance of it; but if the perſon touch'd the ground with his foot, the fire was collected and diſperſed by the globe; and thus, as he touch'd the earth, or not, the fire ceaſed or continued; this ſeems to be a demonſtrative experiment, that this fire is not cauſed by the motion of the inſenſible parts of matter; becauſe the motion in the whole machine, at each inſtance, was the ſame

same in the globe and person who rubb'd it, when he did or did not touch the ground ; but the fire was attracted more or less, by different sorts of substances, or retarded in its passage ; and the man, in this case, only the conductor of electricity from the earth to the glass.

I imagine it will scarce be objected, that this electric fire differs from any other, since they have, in common, the power of setting spirit of wine, gunpowder, and other inflammable substances, on fire ; and thro' the whole following sheets, they are consider'd as one and the same thing by me.

C H A P. III.

Of animal heat, and of the cause of voluntary and involuntary motion.

AMongst the many subjects in physiology, the causes of animal heat, and of vital motion, voluntary and involuntary, have given as much pain in the investigating, and as little satisfaction in the solution, as any part of the animal œconomy. Many different accounts have been publish'd by

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men of great ingenuity and research ; some have attributed this vital heat to the action of the lungs upon the blood, others to the attrition of the solids upon each other.

That neither of these is the cause of animal heat, has been clearly enough proved by Dr. Stevenson, in his essay on that subject, printed amongst the Medical Essays, at Edinburgh ; but is the account which he has substituted in the place of the former, more probable, or less liable to objection ?

After what has been said, in a foregoing chapter, on the real existence of fire, as an element equal with water, earth, or air, it may seem altogether needless to attempt the obviating what Dr. Stevenson has written on that subject. If fire be proved an elementary existence, it can scarce be said, with any kind of truth, that the intestine motion of animal fluids can be the parent of vital heat ; not to say that this very intestine motion in animal fluids, whilst the animal is living, appears to be a mere suggestion, and creature of the imagination, no experiment having been yet made to prove its existence.

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But allowing even that heat is generated by this motion sometimes, for the sake of giving the argument all manner of fair play, it will then be found, at the end, extremely improbable, that motion of any kind can be the cause of vital heat.

According to Dr. Stevenson's account, all vital heat arises from an intestine motion in the animal fluids. The productions of spontaneous intestine motion in fluids hitherto known, are of two kinds; in the juices of vegetables, it produces fermentation, whence arises inflammable spirit, as its first production; and vinegar, which is the second: in animal juices putrefaction.

That this motion which the doctor supposes in these fluids, is neither of the first or second kind, the analysis of the human blood from healthy bodies convinces us, where neither inflammable spirit, acid, or alkali, is to be discover'd by experiment, on blood fresh drawn.

It is true, the productions of putrefaction, such as the volatile salt, may be drawn from the fluids of a sound animal; but then, there are much greater degrees of fire required for that purpose, than an animal can

sustain, and live ; and which, indeed, must totally destroy the union of all its parts, to yield that production. Or after life, the solids or fluids exposed to a certain degree of heat less than human, fall naturally into putrefaction, and yield, by analysis, alkaline, volatile salts.

In the first instance, it is much more probable, that the great degree of fire forms, rather than separates those salts already made in the humours ; and, in the latter, the intestine motion is visible, and the odour which rises from the putrifying fluid offends the sense of smelling ; neither of which are discoverable by the senses, in the blood of healthy persons ; for blood newly drawn, has not the least appearance of this intestine motion amongst its particles.

Another reason, for the believing that vital heat does not arise from this intestine motion in the particles of animal fluids, is this, that in the fermentation of vegetable juices, where this intestine motion is so very conspicuous, the heat seldom rises above seventy degrees of the farenheitian thermometer, to make inflammable spirits to the greatest perfection ; tho' something more to make

make the acid, which is called vinegar; and in animal juices, separated from the body, or in dead bodies, when the humours fall naturally into putrefaction; where the intestine motion of the particles which compose these fluids, is very visible; where it distends and ruptures the vessels, which easily contained them when in health, and where it must be much greater than can ever happen during life, for that very reason; and yet the heat in this putrefactive state, is much inferior to that of health, and consequently of the vital.

Now to say, that this intestine motion, which we will suppose, for a moment, able to produce heat in the putrefactive and fermentative state of those fluids, and which motion, at that time, is so much greater than can be imagined in the fluids of a living animal, is the cause of vital heat, is the same as to say, that a cause of the same nature, tho' less in itself, is productive of an effect greater than a cause of a superior power of the same nature; or that half, or any proportion of that intestine motion, begets more heat than the whole of it can, which is just as true as that the half of any thing is more than the whole.

Farther, it seems also impossible, that this intestine motion of the particles of a fluid can exist, whilst that fluid is circulating in vessels, under the influence of a projectile power. 'Tis certain, that the particles of fluids are not susceptible of having two different directions, in their moving at one and the same time: let us suppose then, that there is some property in the animal fluids, capable of producing an intestine motion in these particles; there is beyond all doubt another, which communicates a progressive motion to the fluids in circulation; and consequently, to every particle of which they consist. Thus then, the two motions imparted to those fluids, must be compounded of those two powers, that which produces the intestine, and the other which gives the progressive, according to their different degrees of force, and beget a motion in a direction different from either of the above mention'd.

Now, without enquiring what proportion each cause of these motions bears to the other, it is proved, by experiment, that the blood is continually impell'd forwards thro' the arteries, to return by the veins; thus

thus even in supposing a power to produce an intestine motion, lodged in the particles of fluids, its influence must be overcome by the greater projectile power, and lost in the progressive direction; because no particles of a fluid can have two different directions at one time, much less a million, (which would be the case in the supposing an intestine motion) whilst the whole body of that fluid is circulating in vessels. The intestine motion then is proved to be absolutely impossible in the blood; because it is always in circulation, under the force of a projectile.

That this is the real truth, may be proved from waters impregnated with vegetable or animal juices, which never stink or ferment whilst they are in a running state, as the water of the Thames, for example, which never ferments or putrefies till enclosed in vessels; and vinous liquors pressed from fruits, never ferment, if you keep them running from vessel to vessel, and racking even checks their fermentation.

It would be reasonable to suppose also, that if the fountain of this animal heat was in the human body, where Dr. Stevenson
has

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has conceived it to be, viz. in the vein before the right auricle ; that in consequence of this, the heat in that part would be much greater than in the extremities, because the blood being continually divided into different arteries, in its circulation; the areas of whose transverse sections are much greater than that of the aorta, must have a motion as much less as the diameter of all these vessels are superior to that of the great artery ; and in the minutest parts or anastomoses of the smallest arteries, the blood is so little in quantity, that almost every particle is exposed separately, to the influence of the cold of the atmosphere which surrounds us ; and thus the heat would have been much less considerable at the extremities of the human body, than in the sinus venosus. Whereas Dr. Martin has found, by very accurate experiments, that the difference is very little.

Thus it appears to me very plain, that it is impossible, or next to it at least, that the vital heat can arise from the intestine motion of the particles of animal fluids.

Besides this of Dr. Stevenson, there is another account publish'd by Dr. Douglas, who

who places the cause of animal heat in the friction arising between the minutest particles of the animal fluids, and the sides of the capillary vessels. Now even granting here, for the sake of arguing fairly, that friction can produce heat, I believe, after examination, that there is very little foundation to suppose it the cause of animal heat.

First of all, in placing friction as the cause of vital heat, you argue only by analogy; this then being acceded to, the analogy must be preserved through the whole, or no fair inference can be drawn from the argument.

But, on supposing this analogous method to be the only true one, how will you overcome this difficulty, that fluids never conceive heat by friction, nor solids either, when there is a fluid between them? Two marble stones rubb'd dry on each other, conceive an intense heat from friction; a cord rubb'd round a post violently, catches fire; but water between the two stones, or the cord soaked in oil, two very inflammable substances, effectually secures all appearance of heat, in the one or the other, from triture; the same would be the event, if the blood was substituted in the place

place of the water or oil: now it seems extremely probable, that the particles of those fluids must undergo a much greater degree of friction between those two heavy and solid bodies, and the two stones as little divided from each other by these fluids as the sides of the smallest vessels are by the blood; and consequently the particles which compose these fluids as much divided into their minima, and yet neither the solid stone, or intervening fluid, the oil or cord, conceive the least heat.

But supposing that the human fluids, in the smallest tubes of the body, are divided in their passage into their minutest particles; that they become as it were a kind of dust (a phenomenon no where to be found in animal nature); and thus considering each particle as a solid rubbing upon the coats of the vessels, considered as solids also (this I think is granting all that can be desired); and yet even here the analogy of friction producing heat, will be insufficient to answer the purpose of causing animal heat.

First of all, to produce heat from friction, the attrition of one body against another must be violent, or one part press'd with great weight on the other, as in loaded waggons,
whose

whose axles take fire without greafe, or the quick motion of a dry cord on wood. Now the animal circulation being much flower in the capillaries than in the great vessels (for the reason given above in the disproportion of their areas), it is not probable that the original fabric of animals had been form'd in this manner; and indeed the velocity of the blood in the smaller vessels is by no means equal to the begetting such heat as the animal, if we reason from analogy; for an attrition of the fluids on the solids, equal to the producing such a degree of heat, would abrade the coats, and destroy the very vessels which contained them.

Secondly, if the attrition of the particles of the human fluids upon the solids was the cause of vital heat, it must follow, that the heat generated by this action must be greater in the extremities of an animal, where the capillary vessels are in greatest abundance, than in the great vessels of the aorta and cava; the contrary of which is known to be true, by experiment, since the blood in the large vessels is rather hotter than in the less.

Thus then it seems also, in allowing Dr. Douglas all he himself would ask, that it is

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next to impossible the vital heat can arise from the attrition of the fluids on the solids.

The cause of voluntary and involuntary motion, has been as variously explained, and as differently attempted to be accounted for, as that of vital heat, and with as little success; some physiologists have chosen to account for it, from animal spirits acting upon the muscular fibres, which they imagined vascular; others from vibrations of the nerves, produced by æther; a third, from elasticity in the nervous fibres. Now the existence of the nervous fluids, animal spirits, or æther, has never yet been proved, the fibres have never been discovered to be vascular, and the nerve itself by no means seems situated, nor contrived in its make for vibration, and experiment plainly shews that it is not elastic.

Thus it appears, that hitherto no satisfactory explication of the vital motions has been given by any of the physiologists which have written on that subject, though ingenuity may appear in each of them; for certainly, if after having adopted certain principles, some uniform system is produced, that does not contradict itself in every paragraph, the author must be allowed to have merit in
his

his production, though the very first principles are never found to exist: there is ten times more ingenuity shown in combining a hypothesis uniformly from visionary causes, than in making ten thousand experiments, and not applying them to some useful purpose; the first must be the effort of genius, the latter of chance or mere animal activity, inflamed by a curiosity which does not love to be unemployed, and is fond of the appellation of philosopher.

Since the publication of all the above ways of accounting for animal motion, and solving the difficulties which attend them, and during the time of writing the following sheets, there have appeared two different essays on voluntary and involuntary motion in animals, one by Dr. Whytt of Edinburgh, and the other by Dr. Simpson of St. Andrews; the first of which, setting aside all mechanical powers, has endeavoured to satisfy the doubts of physiologists, to clear up the difficulties, and to account for the phenomena which attend motion, from three words only, Stimulus and Sentient principle; and, without letting his readers into the knowledge of what idea he has affixed to each of these

these words ; in what manner words may probably operate on our bodies, to produce animal motion ; or indeed what power produces those effects in the muscular parts of an animal ; he would have us implicitly believe, for surely it can be nothing but faith where nothing is explained, and every thing asserted, that this word Stimulus lies in the blood, which entering into the ventricles of the heart, instigates the word Sentient principle to run to this attack, and expel the enemy, without in the least discovering to us by what method the one or the other actuates the human frame and its parts ; and after having said this much he conceives it absurd to pretend to give any account for the animal motions, on mechanical principles, and concludes it impossible.

Through this whole essay he appears extremely jealous of the honour, and fond of vindicating the superiority of his sentient principle above matter ; not considering that, in thus explaining its powers, endeavouring to place it above the mechanic laws of matter, and distinguishing it as the supreme cause of motion, he has unluckily subjected

it to the obedience of the blood, which stimulates the heart, by entering into its ventricles; for he will scarce assert, that the sentient principle can refuse acting upon the heart, and disobey the summons of the stimulus, at that moment: and thus, in endeavouring to exalt the sentient principle above matter, he has reduced it to the servile and necessary condition of being a slave to the dictates of that brute substance matter.

One thing, however, surprizes me much, in this manner of accounting for the motion of the heart, which is, that he did not reduce it to a more simple cause; and assure us, that the heart beats first in a foetus from an appetite which it has to beat, as he does that a child first breathes from an appetite to breathe. If this appetite be like that of hunger, children must certainly be extremely greedy to satisfy it, when they are born at the end of full time, because, if they are born in the seventh month, they very often have this appetite, and breathe accordingly; and a delay of two months by postponing the object, must greatly inflame the desire of having it. It has been no uncommon thing to adopt false principles, and then frame an hypothe-

his upon them, to support a system, or manner of resolving the phenomena of animal nature; but this seems the only one which has lately appeared, where words alone, separated from all ideas annexed to them; and all explication of the manner of the operation which they effect, have been imagined sufficient to account for any physical effect.

When the doctor tells us, that the heart of a viper, after it is separated some time from its body, vibrates from irritation and a sentient principle, from a prick of a pin, for example, which summons the sentient principle into action; would it not be as sensible to say, that a clock or watch is moved from the stimulus of the spring or weight, which summoned this same sentient principle to the continuation of its motion? Or, that the duck and flute-player, made by Monsieur Vaucanson, were moved by those two causes, a stimulus and sentient principle. It is true, if you please, the masters and makers of those machines, know on what principles they act and move; but the world in common knows no more of them than Dr. Whytt does of those which produce the motion of the heart, and other parts

parts of the body ; and consequently, it would be no more absurd in it, to attribute the motion of those machines to the sentient principle and stimulus residing in them, than it is in him, to the same causes residing in the heart, after it is taken from the body, especially when the motion before and after may be accounted for in the same manner.

In truth, what has he done but applied two expressions instead of two causes ; and, in the end, are we one jot more acquainted with the cause of animal motion than before ? He might, with equal reason and propriety, have reduced his two expressions or causes to one, and said, that the heart beat and the muscles moved from a moving principle only.

But as Haller, and others, have made use of the same word stimulus, and assigned it as a cause of the motion of the heart ; let us endeavour to examine what the idea belonging to the word stimulus is. A stimulus then, I suppose, may be defined some extraneous matter affecting our bodies in a singular manner without, or the common contents of the fluids, by being altered in a different manner from what is natural to them, within,

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and in both instances attended with sensation ; for to say that any thing is a stimulus which we do not perceive, or of which we have no distinct idea, with all our attention, as acting upon us, is the same as to say, that a stimulus is no more than what is no stimulus ; or that a cause acting, is in no sense different from a cause not acting : the systole of the ventricles of the heart then, if it is caused by a stimulus, ought to be attended with different sensations from those which attend the diastole ; and yet this, by all kind of scrutiny, is not found to be the state of the case.

If it should be objected, that habit has made us forgetful or inattentive to the difference, and thence the indistinction arises, as in a room with a clock in it, custom, after some time, makes us forget or not attend to its clicking, or by living near a smith, usage and time make us inobservant of the strokes of the hammer ; and in a thousand instances of the like nature ; yet this will not solve the difficulty at all, for whenever we please to exert the least attention, we hear every sound ; and whilst this exertion is continued, we cannot avoid being attentive to, and distinguish the strokes from the intermissions ;
and

and no time or habit can effect the contrary in us. Indeed, if the cause which operated, produced one uniform uninterrupted effect, time would wear out our distinct sense of it, and it might be considered as not perceived, as we consider the air as not seen in viewing other objects ; but since this stimulus, according to the idea and nature of it, acts by intermissions, it must create a sense, at that instant, distinct from that when it does not act. Then since, by exerting all the attention the human mind is capable of, we cannot perceive the least difference in the sensations between the systole and the diastole of the heart ; or, which is the same, between the time of the stimulus acting, and not acting, we ought to conclude, that there is no such thing as a stimulus operating in the human body, during the time of perfect health, to produce vital motion. So that, in fact, this way of accounting by stimulus and sentient principle, is no more than changing one word for another ; it may as well be assign'd to the anima, archæus, occult quality, or to any other word whatever ; since all words, quatenus words, are equally powerful to produce mechanical effects.

Nothing appears more strange than this, that men can amuse themselves with the belief of having explain'd the cause of any phænomenon in nature, by mere words alone, detach'd from all ideas of the manner of their operating, except this, that their readers, in general, are contented with such accounts. Self-love indeed, may blind the author very naturally; but the love for authors can hardly be assign'd for the blindness of the reader; and therefore it is not to be urged in their favour, as an excuse.

As to what Dr. Simson has advanced, in relation to the vena cava and pulmonary vein, assisted by the pressure of the atmosphere in inspiration, being the cause of motion in the heart, and distending the ventricles by the force with which that fluid is forced into them; this seems extremely improbable, at the first view: is it likely, that vessels like the veins, in which there is no pulsation, can impart a motion and force to a fluid, sufficient to dilate and distend a muscle so strong, and composed of fibres so elastic as are those of the heart? Not to mention, that the motion must begin in these veins prior to that of the heart, which
will

will scarce be given credit to, by any one who has observed upon the first phænomena of the foetus in the egg after incubation. But, without resting the proof of the falsity of his opinion on this bottom, let us allow, that the veins begin and give the first motion to the blood. All elastic bodies react in proportion as they are acted upon, and all the force the heart can communicate to the blood, is the re-action of that force with which it was acted upon by the veins. Is it probable then, that the vena cava and pulmonary vein can impart a momentum to the blood, that by its percussive and projectile force, in the ventricles of the heart, the fibres which compose this muscle shall, by their re-action, according to the properties of elastic bodies, impart an impulse to the blood, sufficient to overcome the resistance in distending the arterial tubes; and that other, which arises from friction? Methinks the least comparison of the make of the different tubes, the arterial and venal, the small number of fibres which compose all the parts of those veins which Dr. Simson imagines the primary cause of circulation, when placed in competition with the

vast number of the heart, and all the arterial tube, afford an intuitive demonstration, that the veins can never overcome the resistance which must be opposed to them; and consequently, cannot be the power which propels the blood, and dilates the heart.

Was this the true way of accounting for the beginning motion of the blood, why is not the motion and pulsation felt as plainly in the veins as in the arteries? Or, how does it happen, that the visible and strong motion of the heart and arteries, springs from the invisible and imperceptible one of the veins; this is to make nothing the cause of something, or the privation of a cause equal to the reality of its existence.

As to that observation of the motion of the cava in a dog, made by Bartholine, that could not be seen till the dog was opened, and then it was much more probable to be a convulsive than a natural motion; and indeed, too many facts have been taken as real, founded on experiments made on animals in a preternatural state, as they are always, when wounds that are fatal have been made upon them, many of which facts have at last been proved to be falsely establish'd.

In

In this manner, which Dr. Simson has chosen to explain the cause of circulation, and vital motion in an animal, he has assigned no power by which motion is at first begun. What is it which communicates this motion originally to the venal tubes? Or, why does it begin here rather than in the heart and arteries? In fact, the heart, according to this scheme, appears a useless viscus; for by imparting no more impulse to the blood than it receives from the veins, that fluid might as well have passed directly from the venal to the arterial tubes; whence, of necessity, we are by this system led to this absurd, not to say impious conclusion, that in the human structure, the heart is an unnecessary piece of mechanism, a mistake in its composition, and that by a being infinite both in power and wisdom.

In fact, it is impossible, that motion can begin of itself, and the property of elastic bodies is to re-act as they are acted upon; and consequently, unless some reason can be assigned, why the veins act first, this account of the circulation and animal motion must be imperfect, and indeed impossible, even with that supposition, from what has been already said.

That

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That the atmosphere, in pressing on the blood-vessels in the lungs, has no power to communicate a greater motion to the blood than it had before, is plain from this: suppose what power you will, in the weight of the atmosphere, it will by its pressure equally impede the velocity and impulse of the blood in the arteries, which continually become less and less, at all their divisions and ramifications, whilst it is going forward to the veins, and the sides of the arteries are render'd more obstinate by this pressure, and less liable to yield to the impelling power, as it will assist in the propelling the blood, and accelerating its motion in the veins, which become bigger and bigger, at each union of the branches.

But that the atmosphere has no effect, in continuing the circulation of the blood, is sufficiently demonstrated by the circulation in the foetus in utero, where it is impossible the lungs can impart any degree of velocity to the blood, or communicate any assistance towards the distending the ventricles of the heart, because they do not move.

What can be a greater proof, that the pulsation of the heart is not caused by any
force

force communicated by the blood to that viscus than this, that hearts separated from the body, where no fluid comes near them, can be put into the same actions, without any fluid at all, by the simple prick of a pin, or a little heat? This Dr. Simson foresaw; but has by no means got over the objection and difficulty which attends it.

Notwithstanding what has been said, to show how ineffectual every attempt to account for vital motion hitherto offer'd to the public, has proved; it must be allow'd, that there is but little merit in destroying the works of other men; a very mean architect can deface a ten times finer building than he can design, and a hand can destroy St. Paul's, that cannot even build a hovel.

In order then, to give the physiologists a fair opportunity of exerting the same talent in their turn, let me lay before them, the manner in which it appears to me, that those two phænomena in natural philosophy, of vital heat and vital motion, may be explain'd and accounted for.

The better to succeed in this endeavour, let us begin where the cause of those two effects begins in nature, and trace this vital
heat

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heat and motion from its source. This, perhaps, may assist us in explaining these phænomena more clearly than it has hitherto been done.

An egg, tho' it include all the parts necessary for the formation of an animal, will never produce a chicken without being contain'd in a certain degree of heat for a certain time; which heat, regularly conducted, is all that is necessary to the production of an animal similar to the parent.

That there is nothing more necessary to the producing this animal from an egg than common fire, has been long known and practised in Ægypt, and lately demonstrated by infinite experiments made by monsieur du Reamur; no vital principle transfused from the hen to the embryo, more than the effect of common fire.

Nor will it make the least alteration in accounting for the effects of this heat, in the first communicating motion to the cicatrix, whether you suppose it in the first day of incubation influenced like seeds or pulse in the earth, by warmth and moisture, or consider it as an animal in miniature, already formed; because, after the chicken is un-

doubt-

doubtedly form'd in the egg, if it be deserted by the hen, or the heat discontinued, diminish'd, or heighten'd a few degrees, the animal no longer lives in the shell. Thus it is plainly prov'd, that fire is the first mover in the animal machine; and I believe it will be found, the only active principle, during its existence; a certain degree of which principle is absolutely necessary for the preservation of health, and generating wholesome fluids.

After so many repeated experiments on that effluvium, which has hitherto been called electrical; after having discover'd so many phænomena, which are no ways to be distinguish'd from those of fire; it will scarce be any longer disputed, that they are the same in their own nature; or, that after this fire produced by electrical experiments, has been perceiv'd by all our senses, that there can be less reality in it than in earth, air, water, or fire; the reality of which, with respect to mankind, depends on the evidence of those very senses; and which, I hope, has been proved already in a previous chapter.

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It appears to me, that this fire produced by electrical experiments, is no more than the solar rays, which had been dispersed thro' the earth, and collected again from it by electrics, per se, whose particles have been put into agitation by friction.

However, whether this last suggestion be true or false, this electric effluvium, in its own nature, can scarce be deem'd different from fire; and it has been shown, by undoubted experiments, that human bodies are greatly charged with this matter; that it operates very strongly on the muscles of an animal, and that it is attracted by the human body, since many of them yield the appearance of sparkling, with being rubb'd only.

Let us now take some of the properties which have been discover'd in this electric fire, by repeated experiments already publish'd; the make, mechanism, and properties of the muscular parts in an animal; and by applying the effects of one on the other, let us candidly endeavour to give some account for the beginning and continuation of vital heat, and vital motion, voluntary and involuntary.

The first property of this fire, is, that it is collected easily by some particular bodies,
when

when the particles of them are agitated by friction, and by others not at all.

It is conducted by others at vast distances, after being collected by the former.

The first of these bodies are called electrics, the other non-electrics.

This fire, when it is collected by the globe of glass, must pass from the earth thro' some conductor; and when the globe is rubb'd by the hands of any person, it passes from the man to the globe, and from the earth to the man.

This fire acts upon fluids, in repelling their particles from each other, which causes a dissipation and evaporation of the fluid.

This fire, like the rays of light, acts by pulsations.

The nerves are the conductors of this fire, from one part of the body to the other.

Several kinds of substances are more adapted by nature than others, for the containing a larger quantity of this fire, as quicksilver, iron, water, as hath been discover'd by monsieur le Roy, of the academy of science at Paris, by the electrometer of his invention.

The fibres of all muscles are elastic.

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These fibres are join'd to one another, by other fibres which cross their longitudinal direction; every fibre in a muscle, even those discover'd by the microscope, is surrounded by the tunica cellularis.

All the nerves which go from the brain, or medulla spinalis, terminate in, or perhaps form, this tunica cellularis, being no more than an expansion of the nervous substance.

The tunica cellularis, as its name expresses, is composed of an infinite number of small vesicles communicating with one another.

This cellular tunic is found in a much greater degree in the belly of a muscle than in the tendons, if at all in the latter.

The better to apply the powers and properties of this fire, on the mechanism of a muscle, and to explain how this fire operates in producing the vital motions, and the continuation of itself in an animal; let us begin, by supposing the animal already form'd in the egg before incubation, and wanting nothing but the application and influence of heat, to put its solids and fluids into motion; and which is truly the case, as every day's experience gives us a demonstration of.

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The first alterations which are visible in the growing embryo, by the communication of heat to the cicatrix, are the punctum saliens, or beating of the heart, and the change of white particles into the red globules of blood; tho' Bellini de Motu Cordis, in speaking de Ovo; and the first appearances which follow the application of heat, says, that the nervous system is the first which is expanded by the heat of incubation. This being true, it will add much force to what will be hereafter said, in relation to the nerves, viz. that these being the conductors of the vital fire, it is necessary that their encrease or expansion should be as early as possible in the new being, to give and continue life and action to the parts of involuntary motion.

It is evident from this author, that he conceived that all the motion of the heart and arteries was first begun in the fœtus, by the simple application of heat alone, without any other power arising from the animal spirit or nervous fluid, which he imagined as necessary to the life of an animal, after leaving the womb. This seems to me the more extraordinary; because he has supposed

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that this, which is equal to the giving life, is unequal to the sustaining it, and not adhered to fire or heat; and rejected the imaginary existence of animal spirits. What is there in the motion of the heart of an animal, after birth, different from that which it had before? and why, since fire has the power of beginning this motion, in the womb or egg, has it not the power of continuing it, after the birth?

It will not seem unnatural to imagine the original state of that muscle before it begins to move, like what it is found in the animal body after death; because the heat of an egg before incubation, and of an animal after expiration, are of the same degree; that is, the heart is neither, in its systole nor diastole, contracted or dilated, but in its perisistole or intermediate state between the other two.

Let us now recal the power lodged in fire, of repelling the particles of fluids, which are non-electrics; of acting by pulsations; the formation of the heart; that a fluid is lodged in the cells of the cellular tunic; that this membrane surrounds every fibre in the heart; and that each of these fibres is elastic.

Thus

Thus then, the first communication of heat from without, whether by incubation from the hen, or any external fire whatever to the foetus, will be carried by the nerves, and dilate the fluid in the vesicles of the tunica cellularis; and thus dilating every vesicle must distend every muscular fibre, and increase the volume of the heart; for supposing the heart for a moment like a bunch of grapes, with fibres running over them every way, either tied together or not by other fibres; in this instance it will have the same effect, and each fibre elastic. Now this is certain: whatever power dilates each single grape will dilate the volume of the whole bunch, and consequently extend every fibre that passes between them, more as they are united by intersecting fibres than if not, as shall be explained in applying this fire to the producing voluntary motion, when we talk of muscles fastened at each end. Thus then, in the heart, this fire passing to the fluids in the tunica cellularis, and operating by its explosive force on the fluid in the vesicle, the whole heart is dilated, and the fleshy fibres extended; but, as it is the nature of fire to act by pulsations, and of

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elasticity to re-act, after being acted upon; the fire having finish'd its operation of distending the vesicles of the tunica cellularis, and of lengthening the muscular fibres, passes off thro' the body; at that instant the elastic power takes place in its turn, and contracts every individual fibre of the heart, in its length; and consequently, the diameters of the ventricles, which must have been distended by the influence of the fire, together with the distension of the whole heart, are contracted by this elasticity in the fibres: and thus the blood which it had receiv'd, is propell'd from thence into the arteries, which arteries being dilated by the same elementary influence, and contracted by the elastic power of the fibre, the blood is driven forward thro' the whole arterial and venal tube, the circulation supported and continued thro' the animal, and the involuntary motion of the heart, auricles, and arteries, accounted for by those alternate powers of dilatation and contraction.

For in the arteries, as well as in the heart, whoever considers but one moment their form, that their fibres are elastic, and surrounded

rounded by the vesicles of the cellular membrane, he must know, that every dilatation of the vesicles must dilate the diameter of the artery; as in a ring, for the sake of explanation, if you suppose the whole circle form'd of little vesicles, every distension of these vesicles will encrease the diameter of the ring; and thus, the artery will be increased in its diameter for the same reason; and as in the heart, the elasticity of the fibres succeeding to act, after the distension imparted by fire to the cellular membrane, the pulsation is continued in this method.

This manner of accounting for the arterial motion, seems to correspond perfectly with the contexture and fabric of an artery; the difference of thickness between these and the venal vessels being very extraordinary. Dr. Wintringham, in his very ingenious treatise of experimental inquiry on part of the animal structure, having proved, by experiment, that the descending trunk of the aorta was one ninth part of an inch thick, and the vena cava corresponding to it of the same subject, no more than one part of an inch, divided into one hundred fifty-four parts.

This seems to shew the mechanism of the arteries, where the cellular tunic being much to be employ'd, it was necessary that it should be dispersed largely thro' that tube, to actuate and continue its pulsations; whereas the venal tube being design'd to have no pulse, there was no necessity of communicating to that vessel the membrane which is necessary to give motion to every part.

In this method of explaining the motion of the heart and arteries, that moving power which the blood demands for its beginning, and being continued in circulation, is amply supplied; and that loss of momentum which it must have suffer'd in its passing the vessels of the animal body, which is shown to be so great by physiologists, if the whole projectile power had been lodged in the heart, is totally taken off and annihilated; because every possible part of the arterial tube, by this manner of acting, has the source of dilatation and contraction in itself, and of consequence, a power of continuing that motion which was first imparted to the blood by the action of the heart; and at the same time it affords a solution of that difficulty which accompanied the believing, that the whole

propulsive force which continues the circulation, lay in the heart alone; and that its power was so great as anatomists have bestow'd upon it, to support their manner of explaining the circulation; because in this method of accounting for it, there is no greater force of the heart required, than is just sufficient to put it into motion, by delivering the blood in each pulsation, into the arteries; and then the arteries continue it with much ease, by the same propulsive powers acting in them.

This way of accounting for the action of the heart, affords us a reason, why the heart is not furnish'd with more nerves than the other parts of the body; whereas, had the power of this muscle been so great, necessarily to continue the circulation; it is probable that it would have been supplied with nerves in proportion to the demand which was necessary, as are all the most powerful muscles of the animal body.

Supposing, by analogy, as we ought to do, that all the fibres in our bodies suffer alike, in a weakness brought on by some disorder, which acts in general upon our whole composition,

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position, we shall find great reason to lay aside all belief, that the heart is capable of acting with such prodigious force, as some phyfiologists have so liberally assign'd it.

We find very often, that people are reduced by sickness to so feeble a condition, that ten pounds is too much to be lifted by the exertion of their whole powers; and yet the heart continues to have strength sufficient to overcome all that resistance which arises from the weight of the blood and friction which it must meet with in its circulation; which appears to me improbable that it could do, supposing all that force is required by nature for continuing the flowing of the blood thro' the body; for either you must imagine, that the heart and its fibres do not suffer with the rest, in this general weakness, a thing scarce credible; or if they do, and that so much force is required to be placed in it for doing its office in this feeble state, then that increasing in power with the other fibres of the muscular parts, as health returns, the projectile force in it would be too great, and rupture all the blood-vessels; which it does not. This, I think, confirms the

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the truth of the above account of its cause of motion; and the difficulties which have made the accounts hitherto given by other writers, almost impossible, become so many proofs of the truth of this, which has been just assigned.

Another advantage, which arises in this way of explaining motion in animals, is this: the cellular tunic, so universally spread thro' the whole body, has a use assigned it, equal to its universality, and the frivolous reasons of its adding beauty, which is always form'd from what we are accustomed to see, and which we never could have found the deficiency of, if we had never beheld its effects, as well as many other, are shewn to be inadequate to the giving a reason for the forming such a general part of us as this membrane makes; and to me it appears amazing, how its utility and office could have been so long over-looked.

In this manner of explaining things, the circulation of the blood; and vital heat, seem to have been begun and sustained in the chicken, during the time of incubation, whilst this fire is communicated to the egg, from some external body.

Let us now endeavour to explain, how this heat and circulation, in consequence of it, are continued after the animal is born, and it can no longer draw its supplies from its former source.

It is certain, from the experiments of Harvey and Malpighi, that, during the first days of incubation, the heat communicated to the cicatrix has the power of generating in the humours of the egg received into the vessels of the embryo, those red globules which after form the crassamentum.

The animal heat, after the foetus has quitted the parent, is always in proportion to those red globules, or crassamentum of the blood, from the experiments of the ingenious Dr. Langrish.

These red globules are electrics per se, and being dry'd, exhibit the phaenomena of rosin, by flashing in a candle, after being powdered.

The human body is a machine, continually drawing fire from the earth, and communicating it all around, or passing it off by its pores, as shall be shewn by an experiment made by the Pere Bertier, at Paris, and described immediately.

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These red particles then, being generated in quality and quantity, sufficient to attract this fire from the earth, and being once put in motion, continue still to attract it from the earth ; by which all animal motion is continued and supported.

This fire passes by the nerves, which are non-electricals to the brain, and spinal marrow ; and from thence continually to the heart, for the supplying the cause of involuntary motion, and is held in other parts of the brain and spinal marrow, to afford that fire, which is wanted above the common distribution, which always goes to the muscles at particular times, for the performing voluntary motion.

It does not seem improbable, that the vegetating power, operating all the year round in ever-greens, may be owing to those trees having more rosin in their composition than others, whose leaves fall in the autumn. This rosin, perhaps, being in continual friction in its particles, by the agitation caused by the winds upon the trees, or from the dilatation and contraction, by means of the different degrees of the external heat acting on the parts of the wood, which may beget a friction amongst
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its particles, or by holding more of those particles than plants without rosin; either of these may cause an attraction of the fire from the earth, and with it, as it naturally does, the juices which continue the verdure all the year round; and thus supply in some degree, the absence of the solar heat.

It will, perhaps, be a little difficult to explain how the motion of the fluids contained in vessels, formed like those of an animal can begin at all, without supposing that the heart and its ventricles are first distended by some power or other; or how motion could have begun at all, without its being impress'd on it by some other power.

If we suppose, that all the vessels in the body, in their original state, are quite full, before circulation begins, with some fluid; and that the vessels themselves are formed like what we find them after life, which is by no means unnatural; it is impossible, considering the contractile disposition of the arteries, which are always contracted during the discontinuation of the circulation, that the heart and arteries, by any contracting power operating upon them, could have moved a fluid into a place different from that which
it

it occupied, without a space given to receive it in some other part, or any stimulus have contracted the heart, upon an immoveable fluid, filling up all the vessels and cavities.

But in thus making the ventricles, distended by the explosive influence of fire, there is room given for the blood to enter into them; by the pulmonary vein and auricle, into one of them; and by the vena cava into the other, the valves hindering it from entering from the arteries: and this seems to be the great use of those particular valves, situated at the beginning of the pulmonary artery and aorta, that upon beginning life, when motion is first imparted to the animal, and in case of swooning by faintness, when we recover, and the heart dilates its ventricles to receive the blood, these valves are to hinder its coming back from the arteries, which would much obstruct, if not totally impede circulation; for the blood, in this case, running from the veins and arteries into each ventricle, there could be no space given to receive it, the direction of its course also destroyed; and thus no circulation could ensue.

But the ventricles being dilated by this influence of heat acting on the vesicular membrane,

brane, there is room given to the blood to enter into them; and this motion of that fluid the valves in the veins promote: and thus the ventricles being filled, the discharge of the blood is made by the contracting fibres, into the arteries, whose valves are contrived to yield to that impulse, and receive that fluid, whilst those of the veins are disposed to hinder its returning by that passage.

And this offers a demonstration, that the ventricles of the heart cannot have their pulsations succeeding each other, but at the same time; for unless there was room given by the blood's entering from the pulmonary vein into the left ventricle, and by the vena cava into the right, there could be no space made to receive it into the pulmonary artery, as it is discharged by the right ventricle, and into the aorta, as it is discharged by the left: thus both ventricles must move at one and the same time, or there could be no space given to receive the propell'd blood, and consequently no circulation.

Hitherto, it has been supposed, by those that imagined the fibres themselves vascular, and alledged the existence of animal spirits, that

that the heart was contracted by the influx of those spirits, into those cells in the fibres. But in allowing it to have been true, that the fibres were vascular, and that such a fluid as animal spirits existed, even then nothing can be imagined more unmechanical, or shew a greater inattention to the powers of bodies acting one on another, than this assertion; and, in truth, it must have been impossible that the heart, made as it is then supposed, could be contracted by the influx of any fluid into the vesicles in the fibres; for it is certain, that whatever enters those vesicles, whether in the fibre, or any other part, it must have dilated the whole body of the heart, because every vesicle must have been increased in every possible diameter; and thus, the heart in its whole dimensions. The assertors of this contraction by the influx of animal spirits, did not consider that a muscle, fastened only at one end, like the heart, must have a very different effect upon being inflated, from that muscle which is fastened at both ends; and that the same power which dilates one must contract the other, as shall be shown in the following sheets.

That the account we have offered of the dilatation and contraction of the heart, is

the true one, an examination into the mechanism of that viscus will sufficiently convince us.

The spiral direction of the fibres, intersecting one another in their direction, being all elastic, must necessarily draw the whole heart into the least volume, and are thus formed to exert their re-action, after being distended by the fire acting in the tunica cellularis, to the greatest advantage; and which re-action is always proportioned to that power by which they are acted upon.

Indeed, the whole fabric of the heart seems contrived to guard against the ill effects which may be produced by too violent a degree of vital fire, and adds new force to the truth of assigning its pulsation in this manner.

In the internal surface of the ventricles, the fleshy columns, and tendonous parts that pass from one part to another, and intersect each other, yield a convincing proof of this truth; the tendons, whose fibres are very little, if at all surrounded by the cellular membrane, seem designed to prevent the too great dilatation of the ventricles, when they are influenced by too great a degree of vital fire, and to re-act by the elasticity of their

fibres in the systole, in recovering from their distention, and the fleshy columns themselves, during the dilating influence of fire on the cellular membrane, being actuated upon in the same manner with the fibres of the heart, are a counter-action, in this moment, to the too great distension of the heart; thus the very power which distends the heart in other parts of it, here preserves it from being distended too much; and in the systole, when the elasticity takes place in the fibres, the fibres of these columns re-act, to oppose the too great re-action of the first extended. Hence it appears, that the fabric and mechanism of this viscus, is originally and truly formed for being actuated upon, in the manner before mentioned.

The great inducement, which has led physiologists into the mistake of explaining the contraction of the heart from the influx of animal spirits, into imaginary vesicles of the fibres, arose, I imagine, from the facility they found, in explaining the contraction of those muscles which are fastened at both ends by this influx of those spirits.

But a small matter of examination, tho' it has hitherto passed unobserved, will satisfy

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us, that a muscle fixed at each end, though formed alike in every other circumstance, must, from that single consideration, have a very different effect from a muscle, which is fixed at one end only, though influenced by the same explosive power of fire.

The number of ganglions may be considered as so many little brains, or reservoirs, filled with that fire, to supply the source of motion, upon all emergencies; it seems also probable, that more of these parts are nearer the heart than to any other viscus, that the supply might be more certain, and nearer at hand; that if, through failure, in any particular part of a nerve, or from some disorder in the brain, less fire might be distributed from that part, those ganglions might afford a sufficient quantity to perform the office of dilating the heart; for the motion of this muscle is that which, of all others, will the least bear a cessation of action, and life still continue uninterrupted.

Is it not probable also, that the design of the water in the pericardium was originally intended, among other uses, to absorb, and communicate this fire, which is to be carried off by the trachæa, in expiration, along with the

pulmonary perspiration? otherwise the encrease of heat might have been too great in that part.

It is experimentally proved, that aqueous liquors are extremely greedy of receiving this fire, and seem as designed by nature, for the vehicle of it, in many instances; it is certain also, that it pervades all animal substances, and passes by the nerves, without waiting for the tedious laws of circulation.

It has been already observed, that this fire acts by intervals or pulsations; and this may afford some explanation for the alternate motions of the systole and diastole of the heart and arteries; after it has once begun to actuate the heart and arteries, in this manner, it is not at all improbable, but that the pulsation of the arteries in the brain, by the shock which they give those parts, may contribute to the distribution of this fire to the heart, by intervals; and thus this fire being discharged by each contraction of the heart and arteries, a fresh quantity is again supplied by the attraction of the blood, and communicated to the brain; or it is demanded by the heart, having by the last systole discharged the quantity which brought it below what it should have naturally; and thus, as it is

the nature of this fire to rush into every vacuum which is made for it, the heart is rapidly supplied, and the motion of the diastole and systole began, continued, and supported, and animal motion and vital heat produced from the same source.

The many different divisions of the brain, by sinuses, which contain the blood, by the falx and boney divisions, which are all electrics per se, are perhaps designed for the separation, and preserving this fire in different parts of that viscus, the more readily to distribute it through the nerves to all parts of our bodies, as nature and action require, and to hinder that confusion in the brain, which might have taken place, if each part of our bodies had not its separate division to supply it.

C H A P. IV.

Of voluntary Motion.

THUS, after having endeavoured to explain the causes of vital heat and vital motion, which is involuntary in the heart and arteries, let us see if those motions which are called voluntary, can be accounted for from the powers and influence of this fire, under the

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dominion of the will of animals ; for that the beginning, continuing, and ending, of those motions depend on the will, is very certain.

Does it seem then less probable, that this fire (the reality of whose existence is proved by all the demonstrations which can attend the proof of any existence, and the properties of which are known so perfectly) is lodged in the brain, medulla spinalis, ganglions, and nerves ; and thence operates on all the different parts of the body, than to imagine the existence of animal spirits, which no experiment has discovered, nor any eye beheld, or of an æther equally indiscoverable by all the sagacity and research of the human faculties, or to the elasticity in the nerves, which property they have not the least title to, as is apparent from their texture and situation, especially when all that seems necessary for explaining vital heat and motion is found in the qualities of this fire acting on muscles formed like those of animals.

Nor is it at all unnatural to imagine, that this fire is contained in the brain, and similar substances surrounded with the bones, or fat, which are a kind of electrics per se, in greater quantity than in other parts of the ani-

mal body, since, by experiment, we are convinced that several sorts of substances are more adapted by nature than others, to retain this fire : spirit of wine, for example, will hold a quantity sufficient to put it into a flame ; water, mercury, and iron, surrounded with an electric per se, can be charged with a much greater quantity, from the electric machine, than many other substances, as is seen in the Leyden experiment of the phial filled with either of these substances.

But in thus supposing, that there is more of this fire lodged in the brain and similar parts, than in others of the animal body ; we do not imagine that it is in much greater quantity ; nor indeed is it necessary, because every diminution of this fire, by motion or perspiration, is immediately supplied from the earth ; and consequently, as this matter is wasted by the necessary demand for muscular motion, and otherwise, it is in proportion supplied from the earth to the animal.

In allowing this to be the truth, the heat distributed to the limbs and muscles, when they rest in active, arises from the fire passing from the nerves, which are destined to continue motion in the arterial tube ; and that
lesser

lesser degree which is always distributed to the tunica cellularis. When no voluntary motion is performed, this heat is just sufficient to give a degree of tension to the fibres of the muscles, and by keeping an equilibrium between the action of the explosive power in the cellular membrane, and the elastic in the fibres, render the muscle at all times ready for action, by the influence of this fire directed to it by the will.

It is from the different properties of this fire in the human body, that the *strictum* and *laxum* proceed, and not from any alteration in the fibres themselves being more or less braced up, amongst which bracers, cold has been imagined to be one, when, in fact, whoever will observe the muscular parts of an animal, with the least attention, will find them more braced when they are hot, and relaxed when they are cold; and this in proportion to the heat and cold: or otherwise the muscular parts of dead bodies must be harder than those of living, which I believe will scarce be found true.

The putting the muscles which belong to voluntary motion, into action, depends entirely on the greater quantity of this fire de-

terminated thither by the act of volition, at any particular moment ; and from this greater quantity of fire at that time distributed, arises that greater degree of heat in those parts, than what is found in them when they are at rest.

It is very probable, also, that the nerves which are destined to the sense of feeling, are the conductors of this fire to the brain and similar parts ; and that those nerves destined to motion are the conductors which bring this fire back to the muscles. By this means there is a continual circulation of this fire, and the improbability of its coming and returning by the same conductors avoided.

That the mind has a power over the muscles which are employed in what is called voluntary motion, is indisputable ; the mechanism then which is found in them, and the matter, and its properties, which acts upon them, for the putting them into action by the order of the will, and the manner in which this action is performed, are the objects of this enquiry.

It seems but little satisfactory to say, that either animal spirits, archæus, anima, stimulus, or a sentient principle, are equal to the
causing

causing vital voluntary motion. It is allowed that the soul has a power of exerting this faculty, but by what agents is the question; and in assigning either of the above words, you only put that which you use in the place of mind, and nothing is explained by it; for one collection of letters, formed into a word, will operate no more than another, in begetting this motion; and thus every word used, without annexing the idea; and every sentence in which it is found, without declaring your sense of that operation by it, must be considered as words only inexplanatory of every thing.

Notwithstanding it may be difficult to satisfy ourselves what the soul is, or by what power it presides over the body, and directs the motion of the several parts of it, yet after having discovered that particular substance in nature which is destined to support vital heat and motion; that the mind has the direction of it subservient to its will; and that the particular form and disposition of the parts of a muscle correspond to the operation of that particular substance for the producing motion in them; after this, it will not be extremely daring to risque the giving an account of the joint effect of one acting on the other.

In a machine, tho' we are great strangers to the causes of elasticity in the springs, or gravitation in the weight which moves it, tho' we may never be able to shew how either of these properties is communicated to them, yet we can apply those qualities, and explain the cause of motion consequent and dependent on those two principles, when discover'd.

This fire then being lodged in the brain, the mind has a power, at each volition, of dispensing it to those muscles which it intends putting into motion; and here, from that very explosive property of fire acting upon the lymph in the tunica cellularis, and that of elasticity in the muscular fibres, will arise an effect quite contrary to that which was produc'd in the heart from those two properties; that is, whereas the heart was dilated in all its parts by this fire, the muscles of voluntary motion will be contracted; and this from the single circumstance of those last muscles being fasten'd at each end.

The better to explain the effect of this fire, and make out what has been just said, let us recollect, that those muscles are composed

posed of fleshy fibres which are elastic, running the whole length of the muscle.

That those longitudinal fibres are tied to one another by fibres of the same nature, which intersect this direction, tho' not in continued lines crossing the whole muscle.

That these fibres, even to the minutest yet discover'd, are surrounded by the tunica cellularis.

That all the nerves terminate in, or spread themselves out to form this membrane.

That these muscles are generally inserted by tendons, around whose fibres there is very little of the tunica cellularis.

That the belly of the muscle is chiefly furnish'd with nerves.

From the muscle being thus constructed it must follow, that the vesicles in the tunica cellularis, when the muscle is at rest, must have the diameters which run parallel to the longitudinal fibres, of a much greater length than that which intersects the fibres at right angles; that is, the elasticity of the muscular fibres exerting their effort to approach the direction of a strait line, the vesicles of the tunica cellularis must be prest out into length between those fibres.

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The mind then, upon any act of volition, determining this fire to the vesicles of the cellular membrane by the nerves, which are the conductors of it, it there, by means of its explosive power, distends each vesicle, and increases that diameter which intersects the longitudinal fibres; and thus operating on the belly of the muscle, brings that limb which it is destin'd to serve into action, by contracting the length of the muscle.

It must be remark'd, that at the very instant this fire acts on the flexor muscle, tho' the whole muscle taken together is shorter than before, yet each fibre, in this and its antagonist the extensor, is lengthen'd.

This shall be explain'd by the following figures.

A. fig. 1. is the longitudinal and transverse fibres of a muscle, with the tunica cellularis between them, as they are in the natural state.

B. fig. 2. The longitudinal and transverse fibres, in the direction they must be at the instant the vesicular membrane is inflated by the explosive fire.

Thus it is seen, that the fire acting upon the fluid in the cellular membrane, will dilate

late those vesicles which are between the longitudinal and each division of transverse fibres of the muscles, and change those divisions from quadrangular figures to hexagonal, provided the transverse fibres cross the longitudinal at equal distances alternately; but if that regularity is not observ'd, the fibres will be lengthen'd in the same manner, and the muscle become shorter; thus the flexor muscle acts; and consequently, by bending the limb at the articulation, the fibres of the extensor, which is its antagonist, become longer. Hence it is evident, that the fibres in that muscle whose body is shorten'd, and in the other whose body is lengthen'd, have their fibres each of them made longer. See the 61 page of the *Hæmæstatics*, to prove the truth of this appearance.

This being the state of those two antagonist muscles, at the time when the flexor is at the end of its action; that is, the flexor shorten'd and the extensor lengthen'd, the action of the explosive power of the fire in the tunica cellularis being discontinued, and passing off thro' the skin with the perspiration, the fibres in the flexor muscle endeavouring by their elastic power to return to a strait

strait line, like a string fasten'd at each end, and pull'd two or more different ways, being let go at the same time the transverse fibres acting by shortening their length to the same intent, and the fibres of the extensor from the same property of elasticity which is placed in their returning to their natural length; at this instant the fibres of each muscle act to the same purpose, those of the flexor, by pushing the member to the situation from whence it was drawn, and the fibres of the extensor operating in the like manner, by drawing the limb to its former situation: but at this time, the mind being willing to continue any action, as walking, for example, determines the fire into the cells of the tunica cellularis in the extensor muscle; and thus, in this second motion of the leg, both the explosive power of the fire and elasticity of the fibres, contribute to one and the same action; and thus it will continue as long as this action of walking is continued: by this means it happens, that this explosive power in the vesicles operates only in the first action of walking, in opposition to the elastic power of the fibres; at all succeeding times it unites its efforts along with it,

it, and they both assist in producing one and the same motion.

In thus accounting for muscular motion, we are greatly assisted in explaining several phænomena which would otherwise be attended with great difficulty, and have hitherto been unexplain'd.

First, the formation of the muscle, and the manner in which it is actuated by the explosive fire, will give a solution of the belly of the muscle being so little increased in its diameter, by being contracted, or first put into motion.

The fibres which pass transversely, and hold the longitudinal fibres together, not suffering them to be divided from each other in those parts, and the inflating power operating in the vesicular membrane, which is between all the fibres, it must follow, that the interstices between those transverse fibres being dilated, the longitudinal ones take the zig zag figure, and thus are extended in length, tho' the body which they compose is shorten'd in all its appearances; but as the fibres are confined to one another by the transverse fibres, the encrease of the diameter of the whole muscle is but little, tho' each

each fibre is much lengthen'd, and every vesicle in the cellular membrane much dilated ; thus, in lengthening the fibres by this mechanism, the explosive power has great influence on the fibres, which by being much lengthen'd, act very strongly, tho' the diameter of the muscle is very little increased.

Another thing which helps to explain this phenomenon of the little encrease of diameter in the contraction of muscles, is this: the first mover acting in the cellular membrane, and not in the fibres, as has been preposterously imagined, and the contraction of the muscles being accompanied with the extension of its fleshy fibres, as the vesicles increase in their diameter, which crosses the longitudinal fibres ; these fibres themselves diminish in their diameter : and thus what is gain'd by the dilatation of the vesicles, is in a great measure lost in the diameter of the fibre ; and in the returning state, when the fibres act, what is gotten by the fibres increasing in diameter, is lost in the diminution of the vesicles : and thus the small difference between the size of muscles acting and being at rest, may be accounted for.

This

This account also explains to us, why the muscular fibres have this zig zag appearance in the time of the muscles being contracted.

It is probable also, from the muscles being so constructed, that after the first contraction of the muscle is made, and the elastic property taking place both in the extensor and flexor; that all opposition from friction is taken off; and that this elasticity in the fibres of each contracted muscle, is adequate to the resistance which would otherwise have been communicated by friction to the motion of the limbs at the articulations, especially when a person is charged with heavy burthens, when the effect of friction would be otherwise very great at some particular articulations.

C H A P. V.

Of Respiration.

IT appears a little surprizing at first sight, that respiration, by no means necessary to life in a certain state of an animal, should so immediately after the birth, be the absolute condition of its preservation. Perhaps, some reason for this may be deduceable from what

we shall say in the following sheets; in the mean while let us apply these universal principles of fire, and of air, to the fabric of the lungs, and thus attempt the giving some account for the cause of respiration.

The powers and properties of fire on muscular bodies have already been explain'd, yet there is another which they have on air.

Air is expanded in all its dimensions, in proportion to the heat or fire which acts upon it:

Air is an elastic body.

The muscles of an animal always act during the time of contraction, and are therefore in their shortest state at the end of their acting.

To succeed in this, let us proceed fairly, and begin with accounting for this action, where it begins in nature; and by candidly applying the preceding principles, let us see if something different from what has hitherto been said by anatomists on that subject, will not be the truth at the end.

Every infant then, before the birth, has its lungs collapsed, the cavity of the thorax filled with that viscus, as far as I have ever been able to observe, the ribs depressed, and the diaphragm up to the fourth rib, the
bronchia

bronchia and aspera arteria almost a vacuum, and the larynx open.

Now, it is certain, that as soon as the child is born, the air, from its natural elasticity pressing every way, must rush into the head of the wind-pipe, and pass immediately into the vesicles of the lungs; and as heat has the power of rarifying and giving a new spring to this air, the vesicles of the lungs must be expanded every way, and the lobes distended by this rarifying air; thus the thorax must dilate also, from the same cause, that heat which is in the lungs of the child.

By this means the ribs are a little elevated, and the diaphragm considerably depress'd, as being incapable of equal resistance with the ribs, from the nature of its texture, situation, and size; and thus the rarifying air distending the lungs every way by its natural spring increased by heat, may be consider'd as the first mover in the actions of respiration.

By this first distension of the lungs, it comes about, that the blood which had hitherto pass by the foramen ovale, whilst the foetus continued in the womb, is now obliged to take a different way, and pass by

the pulmonary arteries and veins ; and the former passage by this means is render'd useless. This makes it necessary, that respiration be continued for ever after during life.

By considering the air alone, as the first mover in respiration, the intercostal muscles and diaphragm are consider'd only as antagonist muscles to this dilating power of rarefied air, and only acting by expiration.

It must be remember'd, at the same time that the spring and elasticity of the air is increased by the heat in the lungs, that it grows lighter than the external air, in proportion to the heat which is communicated to it ; and that the diaphragm, intercostal muscles, &c. having been extended by this dilatation, their fibres must in turn begin to act on the expanded lobes by their elastic contraction ; and thus the resistance which those muscles give to the expansion, must determine the air to re-ascend by the trachæa ; hence this new direction being given to the air, it must, according to the laws of gravitation, and the operation of the muscles, continue to re-ascend till all is breath'd out, except that small quantity,
which

which being rarified with heat, still remains in the vesicles of the lungs, and thus hinders each vesicle, and consequently each lobe, from returning to the size which they had before respiration; this is proved by that experiment of the lungs swimming, after having perform'd the action of breathing; whereas they sink without having been used in respiration; which difference arises from this, that each vesicle being dilated, and never returning to its original size, the surface of all of them is increased; and thus the relative weight becomes less than water, tho' the specific continues the same; as an iron kettle swims in water whilst it is entire, and yet sinks very precipitately when broken to pieces. In this manner the first act of respiration is perform'd.

It has been proved above, that the vesicles of the lungs never recover their original minuteness, and consequently that some portion of rarified air must remain in the lobes after expiration: this then will effectually exclude the common air from entering by the aspera arteria. In consequence of this, some new cause of motion must be given to the lungs, or respiration is at an end;

and this same cause was assisting in the first inspiration, and is only mention'd here, as 'tis more easy to comprehend the reason of it.

The lobes of the lungs then, after the first expiration, being distended by the rarified air, they touch the internal surface of the thorax; and this has been the situation in which they have been found in every dead body which I have open'd.

At the same time the whole power of elasticity which was communicated to the air by the heat in the thorax, having been exerted, and no greater heat in that part to communicate a farther force to that air, so as by its spring again to dilate the thorax, it becomes necessary that some new power should be exerted to perform the second action of inspiration; and here it is, that the effects of that fire which is the cause of muscular motion, takes place.

The lobes of the lungs, like every other part of the body, have the tunica cellularis surrounding the vesicles of the lungs which receive the air; this membrane then executes the same office in this viscus which it does in the others.

The

The first expiration being finish'd, the fire which was in the tunica cellularis being carried off by the watery vapour, it returns to that part immediately, to restore the equilibrium; and thus giving the first motion of dilatation to the lungs, the fresh air rushes again into them, by means of the space which is given for its admission by this first action of the vital fire; in this manner they are again expanded by the heat, the ribs are again elevated, and the diaphragm depress'd: thus the actions of inspiration and expiration are constantly and regularly perform'd, by the vital fire returning after each expiration, to distend, and the intercostal muscles and diaphragm, to contract the cavity of the thorax.

It is certain, that the actions of respiration are of a mixed nature, neither altogether voluntary or involuntary; that tho' the will has some power over the parts concern'd in these actions, yet it has not an absolute one; however, the mind can hasten or retard, either inspiration or expiration, can cause us to feign a cough, sigh, or laugh, by determining the fire to the lobes of the lungs, in different proportions and man-

ners, as it is to the muscles of the legs and arms, for the variety of motions which they are capable of exerting.

But it may be expected, I imagine, that some reasons arising from the structure of the parts necessary for respiration, should be brought to justify and support this manner of thinking so different from other anatomists.

First then, the make of the lungs appears to be designed for this manner of acting, by the expansion of rarified air, and not for distension of the weight of the atmosphere, because the lobes being composed of exceeding small vesicles, communicating one with another through the whole lobe ; and the internal surface of them five times as much as the surface of our whole bodies ; the air, which enters then, is divided by those partitions of the vesicles into extremely small portions ; and thus by means of those separations, the heat is almost instantaneously diffused through the whole body of air which is inspired ; thus the air is infallibly quicker expanded, than if the lobes had consisted only of two bladders, perhaps in the proportion of one vesicle to the whole lobe.

As soon then as the air, which has descended into the lungs, begins to be impeded in its expansion, by the opposition which is made to it by the ribs, intercostal muscles, and diaphragm; it becomes heated to that degree, that the instant those muscles re-act, it is disposed to re-ascend, by its levity, thro' the trachæa, and that motion, which is communicated to it by the contracting muscles.

On the contrary, if the atmosphere, by its natural weight alone, was the expanding power, the lobes of the lungs would in all probability have been otherwise formed and composed of much larger vesicles, if not of one only, since, by the present conformation, the air being so infinitely divided by the above-mentioned partitions, the effects of gravity are almost taken off; and thus every division which in the first manner of rarification, operates to effectuate the expansion of the vesicles, by suddenly communicating heat to the whole air inspired, in the latter way of accounting for it by weight, exerts its power to resist this dilatation; and in fact, what can the gravity of the atmosphere effect upon the lungs, when, in computing the number of vesicles, and weight of the air upon them, there
will

will be found not one grain of air acting on each vesicle, which seems much too small a power to expand any thing by its weight, that can offer the least resistance, especially if you consider that each vesicle, though never so small, has yet a smaller orifice, thro' which the air must pass.

There seems not the least reason to imagine, that the intercostal muscles and diaphragm are necessary to enlarge the thorax by their action, to give admission to the air into the lungs at the first inspiration; since the lungs, tho' they do originally fill the thoracic cavity, have yet no air in the vesicles, and thence there can be no necessity for distending the thorax (supposing these muscles have that power) till the lobes have been filled with air, and the rarified air remains after each expiration. Hence it appears, from what has been said, that those muscles are not destined by nature for assisting in the action of inspiration.

It seems then pretty evident, that inspiration may be accounted for from the rarifying elastic air, and the vital fire distributed to the cellular membrane, which is in the lungs.

However, it is reasonable, that since, by this way of accounting for inspiration, I have taken off the use of the intercostal muscles and diaphragm, that I assign them some other use (for some use they certainly have); and here it seems to appear, that when we consider the insertions and directions of the fibres of the intercostal muscles, and of the diaphragm, that, instead of being designed to act in the time of inspiration, it is impossible they can act but in producing expiration, unless you will suppose that those muscles, contrary to the principles on which all other muscles are granted to operate, act by having the whole body lengthened, which I suppose no one will have the hardiness to assert.

But let us examine the make and mechanism of those parts which form the thorax, and first the ribs; those are attached to the vertebræ of the back, by very strong ligamentous articulations, for the most part double: together with the capsular ligaments, and several others, which give great strength to the whole; the heads of those ribs are placed also before the transverse apophyses of the vertebræ, and their curves directed in the most advantageous manner to preserve them
from

from being dislocated, by a too great inflation of the lungs, and at the same time to give the greatest power to the ligaments and muscles.

The ribs are joined to the sternum, by cartilages, in a manner which bespeaks the greatest strength, and not the least apparent mechanism in their union, which can afford the idea of their being designed to be elevated by the intercostal muscles; on the contrary, every part appears to have an opposite tendency, and to convey the idea of violence offered to it in that action.

We see that the intercostal muscles cross each other in the direction of their fibres; the external take the descending transverse direction, from the apophyses of the vertebræ to the sternum; the internal take the contrary direction, and mounting from the vertebræ, intersect the fibres of the former, and sometimes the fibres pass over a second, and are inserted in a third rib; and are at last inserted in the sternum, that is, the fibres of the internal and external intercostals have two different directions between each pair of ribs on the same side of the thorax.

Now here it is evident, that those muscles must have a force compounded of two different

ferent actions, in a direction contrary to both; and that, if those muscles act like all others, during their contraction they cannot assist in the time of inspiration.

First, these muscles are not to be considered as so many separate pair, between each two succeeding ribs; but the whole length of each is to be considered as one muscle fastened at each end to an immoveable point; for certain it is, that when they act, the action is continued through the whole, and not confined to any particular part.

Secondly, the diameter of the breast, from the vertebræ to the sternum, and from one side of the breast to the other, crossing the first diameter at right angles, is greater at the end of the inspiration, than of the expiration; and the ribs farther from each other at the first time than the last.

Thus then the intercostal muscles being fixed immoveably at each end, and the arch over which they pass being much greater in the inspiration than expiration, the muscle must of consequence be lengthened by this inflation of the thorax: hence it cannot act to assist the motion of the breast in inspiration, because no muscle acts by lengthening its

its whole body ; it must then necessarily operate to produce the action of expiration, and is at the end of it, as all muscles are in the height of action, contracted, and the arch which it makes is nearer to a straight line, and the ribs closer to one another.

This must happen necessarily from the muscles being fixed immoveably at each end, so as those ends cannot by any means be made to approach nearer to each other ; the action of the muscles, by their contraction, cannot pull up the ribs, but the ribs being once elevated by the lungs, and the muscles being extended, they must, in their contraction, bring down the ribs. Perhaps this may be explained by supposing a number of segments of hoops moveable upon pivots up and down, between the parts to which they are fastened ; these being placed so as to form the largest diameter from one side to the other, and then crossing cords in the manner of the intercostals intersecting each other, by shortening the cords with wetting, it will be found that the hoops will move and lessen the diameter a-cross the breast, and the cords be nearer to strait lines ; whereas, if these muscles were only fixed above at the

upper extremity, and not below, their only action would be that of elevating the ribs; and if they were fixed below and not above, that of depressing them; but it will be seen that by thus being fix'd at each end, other and better uses result from it, than could have been effected in their being at liberty each at one end.

We have already said, that the force of those muscles is exerted in two directions, each of them different from the direction of the fibres in the muscles, though arising from the united action of both, and which direction arises from the intersection of their fibres, as two powers pulling a weight by two lines that join at right angles, with equal force, gives a direction to the weight in a strait line equidistant from both.

One of these directions then, must be perpendicular or crossing the ribs nearly at right angles with them; and is that which depresses the ribs, and brings them nearer each other. The second in a direction parallel to each rib, by which the force of these muscles is exerted on the ends of the ribs, which confines and secures them firmly in their articulations.

Now

Now it is manifest, that these two different powers and directions arise from one and the same mechanism and action; for the fibres of the intercostals intersecting each other, and acting with equal strength probably, and at the same time; it is evident, from what has already been said, that their force is in the direction of neither of their fibres, but in one compounded of both; for, as the ribs are moveable at each end, one by the articulation with the vertebræ, the other by the motion of the sternum; and as the diameter of the thorax from one side to the other, is greater in inspiration than expiration; and the powers of the muscles in a direction crossing the ribs at right angles, their actions bring each rib nearer to the other, and make each muscle approach nearer to a strait line, and consequently shorter in its whole extent.

And thus it is evident, that the action of the muscles must be exerted in depressing the ribs; at the same time, and by the same exertion arises that other force which exerts itself in the same direction with or parallel to the ribs; for, if the external intercostal acts by drawing the articulated end of the ribs

ribs upwards to the vertebræ, the fibres of the internal operate in a contrary direction, and draw it transversely downwards: and thus these intersecting fibres, by their different directions, exert a power in a direction, compounded of that of each muscle, as has been already explained, and which here is parallel to the ribs; and thus effectually secure all danger of dislocation from too great a force of vital fire distending the lungs.

From this manner of explaining the operation of those muscles, it is visible, that a fuller and better use arises, than if the fibres had run in the direction of their powers, and the muscles crossed each other at right angles, one perpendicular, the other parallel to the ribs; for by this means the ends of the ribs are more firmly secured in their articulations; and held together by two rows of fibres, whereas, in the other they would have been held together by one only.

Having considered the thorax, both muscles and bones, and found it so little disposed from its structure, with respect either to the direction of the one, and articulation of the other, to assist in the time of inspiration; it is now become evident, that this part was ori-

ginally form'd with such strength, for a quite different purpose, not to raise the ribs and enlarge the thorax, but to hinder it from being enlarged too much, when the vital heat is too great, as in some asthmas; in great emotions, and agitations from grief and pain, in excessive laughter, and other accidents which may arise from too long retension of the breath, and at common times to give the expiring turn to the breath, by acting after the inflation is complete.

It is scarce worth while to mention the sternocostals, the ferrati, and other muscles, as assisting in the action of respiration, because those actions have been performed, when every muscle but the intercostal and diaphragm has been divided.

Yet, if any one will take the least pains to examine the sternocostals, the direction, and insertion of their fibres, he will find that they are destined for the office of expiration, or to strengthen the thorax, as well as the ferrati.

Indeed the ferratus superior may, at first sight, seem to have a contrary effect to the forementioned, in its action; but when it is once observed, that its insertions are in those ribs which have the least motion in the

action of respiration, and that it may be even necessary, that there should be some resistance to the descending ribs, lest, by their being too much press'd together, obstructions in the blood-veffels, which run between and serve those parts, might be caused by their being too much straightened and confined; and farther, this very muscle is at least as much adapted to give certain motions to the head, as to any other use.

This last muscle then, can scarce be considered as contradicting the mechanisim and use of the others.

It remains now, that we speak of the diaphragm, and its use: this muscle divides the thorax from the lower belly, its fibres arise from a strong aponeurosis in its center, attached firmly to the mediastinum, which is incapable of being extended lower in animals which walk upright; from this center the fibres go off every way, and are fastened to the bottom of the xiphoide cartilage, to the cartilages of the last true ribs, and to the vertebræ of the back.

This muscle, then, like all others, will not act by contracting in its whole length,

and of consequence must be shorter at the end of acting than at its beginning.

If we examine the make of this muscle well, I fancy it will appear that the mistake which anatomists have been under, in imagining that, by its descent, it came nearer to a strait line, springs from their not attending to the aponeurosis at the mediastinum, where it is fastened, and from whence it cannot descend by any force, so as to make the curve of the whole less; and thus it is, in its shortest state, at the end of expiration. Fig. III. will explain what I mean. A. is the diaphragm suppose, as you see it in fronting the breast: B. where it is attach'd to the mediastinum *c. c.* at the ribs.

Now since the point B. cannot descend lower when it acts, it is impossible the arch *c. B. c.* can be altered, or the line which formed it reduced nearer to a strait line; consequently, when the lungs are thoroughly inflated, the diaphragm not being capable of being forced lower at the point B. the parts between B. and *c.* on each side B. are forced down into two curves, like the pricked lines; and thus it is plain that the
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diaphragm being at this time longer than at the end of expiration, it must act only to promote the action of expiration.

What has been said, I imagine, will prove the truth of what has been here advanced, and show us that hitherto anatomists have been mistaken, in what they have written on this subject.

A very strong evidence of this truth is, the foetus being always found with the diaphragm in the same situation it is in at the end of expiration, and the ribs depress'd; and in this way of accounting for respiration it must be so; for as they have no antagonist muscles, they must be in their contracted state, and cannot have been put into action, till the lungs shall receive the air to dilate them; against which power, these muscles act as antagonists: and this explains why they never can act in a foetus in the womb. Anatomists, in general, not being acquainted with the different properties of air, fire, &c. have imagined that nothing can act but muscles against muscles, and have embarrassed themselves in looking for antagonists for the heart, &c. excluding two different powers acting in one and the same

muscle, as has been explained in the heart, where the expanding power and the elastic, act alternately, and effect on a muscle fastened only at one end, the same thing which is done by two muscles fastened at each end which are antagonists; as in the case of respiration, where the lungs act by the inflating power, and the pectoral muscles and diaphragm as the elastic; and this indeed shows us in what manner the heart acts. If you imagine the lungs doing the office of the tunica cellularis, which is in the heart, and operating to make the diastole, you may easily place the muscles of respiration for the fibres of the heart, which by their elasticity, produce the systole: thus inspiration and expiration are performed like diastole and systole, only what was effected in the heart by two powers in two different parts of the same muscle, is in respiration effected by two different parts in different places, by the same powers.

What Dr. Simson has assigned for the reason of the ribs being depressed, and the diaphragm so high up in the thorax of a foetus, is something very extraordinary; he assigns the weight of the atmosphere acting
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on the abdomen and uterus of the mother, for this fact: I should be glad to know how it is the atmosphere would act upon an animal inclosed in a bladder of water, and how it comes about that the foetus moves all its limbs so easily through this fluid, so greatly press'd by the weight of the atmosphere, or how the muscles of respiration in a child, as soon as it is born, can overcome the weight of the atmosphere, which they must do, according to the account of those who begin respiration with the action of the intercostals and diaphragm.

C H A P. VI.

Of the use of Respiration,

IT remains that we speak of the uses of the lungs: The first of which is, that the child being newly born, is subjected to new wants, which it could know nothing of before that time, hunger, pain, &c. For this reason it is necessary that some means be contrived for the expressing them; and this is done by making the lungs the receptacle of air, which is to be formed into sounds by

the different modifications of the larynx, to express the wants of the infant, as well as to supply speech hereafter, in conversation amongst mankind.

The second is, that by the different degrees of its perspiration, the lungs may regulate and counterbalance the accidents which arrive to the cuticular secretion, whether from different degrees of heat and cold, or from any other cause.

It is manifest, that the discharge by the skin is considerably less in winter than summer, in cold weather than in hot, and yet, as we take in near the same quantity of aliment in one season as the other, it becomes necessary that an equal degree of perspiration should be discern'd every day ; now the cuticular secretion being much diminish'd by the cold, that by the lungs which is analogous to it, becomes greatly increased, as is too well known by all those who are subject to catarrhs, when the secretion is so much augmented in the winter that it cannot be carried off by the breath, but runs tickling down the windpipe, exciting coughs till 'tis brought up.

Let us endeavour to explain, how the cold which obstructs the cuticular discharge may increase that of the lungs.

It is evident then, that in all rarified vapours, the condensation of them is in proportion to the cold which acts upon them; now, as the degrees of summer's heat and winter's cold are very different from each other, the condensation of the pulmonary secretion, which is a vapour in the lungs, will be influenced by this difference of heat and cold, and condensed in proportion to that degree in the air at every inhalation; but the cuticular secretion being much impeded, and the lungs offering a free passage to that matter, the secretion must naturally be increased here, as the stopping one augments the other; by which means it becomes necessary that a greater degree of cold should be received by the air into the lungs, that in every expiration the breath may go out more loaded with vapour; and thus the cuticular and pulmonary discharge are kept in a kind of ballance, the heat that increases the cuticular lessens the power of that which carries off the pulmonary secretion, and the cold which increases the pulmonary secretion

tion increafes alfo the power of carrying it off, and leffens the cuticular.

A third ufe may be this: as the motion and force of the heart is in proportion to the vital heat, and that infpiration and expiration are quicker or slower, in proportion to this heat alfo; and as heat beyond the degree of that of health, has very deftructive effects, fuch as ruptures of the blood-veffels in its accelerated ftate, it may be neceffary to let in cold air as near as poffible to the heart, to oppofe the effects of that fire which might be otherwife too greatly increafed, and at the fame time to difcharge part of it by the vapour which is breath'd from the lungs, and which is always found proportionably hot to the internal heat.

A fourth ufe may be this: the new-born child, which now begins to digeft its own aliment, wants to have the chyle intimately mixt with the blood, before it is diftributed over the whole animal body, to be form'd into nutriment; and this office is perform'd by the lungs, the foramen ovale being fhut by the firft infpiration, the blood is obliged to take another courfe, and pafs thro' the whole body of the lungs, where the mixture with the chyle is perfected.

This perhaps will lead us to account for our not surviving after the birth, without continuing to breathe.

It has been said, that the air entering the lungs, is rarified by the heat which it meets with, and is the sole cause of the first inflation of the lungs. If there be heat enough in the infant when it is born, this inflation must obtain; and thus of consequence, the blood must take a new and different channel from what it did before: now the blood having once past this way, it can no more pass by the foramen ovale, but continues to circulate by the pulmonary arteries and veins thro' the whole substance of the lungs; from this circumstance we shall see the necessity of continuing respiration, or the circulation must be totally obstructed.

It is a known truth, that fluids flow most freely thro' tubes in strait lines, and consequently the impediment to their velocity will be in proportion as those tubes are contorted. Now it is evident, that the blood-vessels of the lungs must be more contorted in the depress'd than elevated state of the lobes; and as the distended and intermediate states are but just sufficient, by the giving a
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more rectilineal direction to the blood-vessels, to let the blood pass thro' them from one ventricle to the other, the depress'd state cannot permit that freedom of passage ; thus there will arise an impediment to the blood's motion. Now, as the heart continues to throw the blood from the vena cava into the pulmonary artery, which is probably an equal quantity at each stroke, and the blood-vessels of the lungs do not continue to discharge the usual quantity into the left ventricle, occasioned by the impediment to the circulation, there arises an accumulation of fluids in the pulmonary artery, which at last fills it entirely ; and thus the right ventricle being fill'd by the vena cava, the heart can no longer perform its systole ; because there can be found no place to receive the blood, and thus an universal stagnation must ensue, without the actions of respiration are continued ; and by this, a problem of our celebrated Harvey is solved. *Cur fœtus in utero non respirans aerem usque ad mensem decimum, ob defectum respirationis non suffocatur ? cum natus in septimo mense vel octavo quam primum aerem inspirat inhibita postmodum respiratione ob defectum aeris suffocatur.*

C H A P. VII.

Dr. Hoadley's account of Respiration examin'd.

DR. Hoadley, in his account of respiration, read before the royal college of physicians, having adopted the opinion of Willis, and those others who supposed that the external intercostals perform'd the action of elevating the ribs, and the internal that of depressing them ; that is, that the first named muscles assisted in inspiration, and the latter, in expiration, imagines he has given a demonstration of the truth of this manner, which the former writers on the same opinion had either neglected, or did not conceive.

He first begins with blaming Borelli for having taken but two ribs to explain to us what he meant : let us see if Dr. Hoadley, by taking three, has at all mended the matter ; and whether it is possible, in supposing things, as he does, the same inferences can be drawn from them, which he draws.

Now, tho' Borelli assign'd a wrong use to the intercostal muscles, yet he plainly saw it
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was impossible but that both ranges of fibres and both muscles must act together; or that the action of one of them must be different from every muscle in the body, and act upon another principle.

Suppose then, that the fibres of the external intercostal were put into action, this would be by shortening the whole length of the muscle. Now the external intercostal, and the internal lying between the same ribs, whatever shorten'd the space between the two ends of the external, must have the same effect between the two ends of the internal; and thus this last muscle would be contracted by the operation of the former; and consequently, instead of being lengthen'd, as antagonist muscles are, by their actions on each other alternately, this is shorten'd by its antagonist: thus it cannot act, because all muscles fasten'd at each end, as this is, act by diminishing their length, and this cannot be more diminish'd; and therefore it cannot act as an antagonist to the external intercostal, but it must act always in conjunction with it, or not at all.

But let us see if the doctor's figure, which he has given to explain and exemplify his
idea

idea of the action of these muscles, does not determine quite contrary to its intent.

Fig. 4. This is the figure in which he supposes AB, CD, EF, moveable upon the ends at A C E, and then he asks you, if it is not plain at first sight, that if *a d* and *a d* shorten, whether they will not pull C D up towards A B? To which I say no; that, according to this state, that A B must be more pull'd down towards C D, that C D up towards A B. and for these reasons,

First then, every action of *a d*, *a d* at the same time it pulls C D to A B, draws A B to C D; and thus of consequence, if there were but two ribs, the action of these lines *a d*, *a d* would draw each line A B and C D mutually towards each other; by which there would be neither up nor down, but an equal approach of each towards the middle space between them.

But in placing these, as the Dr. has done, A B must descend more than C D ascends, by the actions *a d*, *a d*; and for this manifest reason, when *a d*, *a d*, act to draw C D upwards, *e d*, *e d* resist that action, and consequently E F must follow. Now the resistance given to the action of *a d*, *a d*, by
C D,

CD, EF, being double to what is in AB, it is manifest that AB must descend twice as much as CD can ascend; and thus this figure proves, that AB must descend, and not that CD must ascend by the action of *ad*, *ad*.

The same manner of reasoning will prove, that *ed*, *ed*, cannot draw down CD; because *ad*, *ad*, and AB, will resist in the same manner, to the action of *ed*, *ed*.

But, in truth, the figure which is exhibited to explain this opinion, is a fallacious representation of the case; because one of the muscles is omitted between the ribs. Let us place them as they are in nature, and then see if it is possible they can have contrary actions, one act by pulling up, and the other by pulling down the ribs.

Fig. 5. Thus the two intercostals are express'd by the lines *add*, and *edd*, as they are in nature. Now let us suppose, that *add* act thro' their whole length, will not the added lines *dd*, *dd*, pull up the EF, as well as that CB; and when *ed*, *ed*, pull down CD, *dd*, *dd*, pull down AD, and during the alternate actions of the line *add*, *add*, will not the line *edd*, *edd* be shorten'd,
and

and so vice versa. How then can these muscles which are represented by these lines act as antagonists, when they are both lengthen'd and both shorten'd at the same time.

During this explanation, we have all along supposed, that the ribs are as near each other in inspiration as expiration, for the sake of giving all the scope which could be to the doctor's argument; but this being known not to be the case, it is impossible the external could have acted to elevate the ribs, unless it acts by the elongation of itself, which is contrary to all other muscles fasten'd at both ends. Thus then it is plain, that these figures prove the contrary to what Dr. Hoadley intended they should have done, and that each intercostal must act at the same time, and to the same purpose, as has already been shown.

There is yet another reason why these actions of pulling up and down, do not seem to be the true design of these muscles, which is this, that perfect intelligence which appears so manifestly to have form'd and directed all the movements of the human frame, upon the most advantageous princi-

ples, and to the most useful ends, would certainly have proceeded in the same method here, which it has in other parts of our bodies.

Now, if elevating the ribs by one muscle and depressing them by the other, had been the intent, it is highly probable these muscles had been otherwise disposed; because, for the elevating the ribs to the greatest advantage, it would have been better to have fix'd one of these muscles to the clavicle, and then to have made the fibres run down crossing the ribs, and be inserted in the last true rib; by this method the clavicle had been a fix'd point to draw from, and the force had been exerted in drawing at right angles; the other might have been fix'd to the false ribs, which, considering the operation and situation of the serratus posticus inferior, may be consider'd as a fix'd point also, and thence running up to be inserted in the first or second rib, would have drawn at right angles downwards; thus they had been antagonists, and no force lost by the application of their powers; whereas, in the way of drawing up and down, assign'd them by the doctor, the power of drawing is lessen'd, in proportion

tion as the intercostal fibres deviate from drawing at right angles ; and thus, I think, those two different actions cannot be attributed to those muscles ; because it might have been better design'd, and must have been by the supreme intelligence.

The next singularity which appears in Dr. Hoadley's account is, that there is air inclosed between the lungs and thorax, in the breast ; and that this air is necessary for respiration. We shall endeavour to prove the improbability of this, by shewing, that if air does pass thro' the lungs, and tarry in this cavity, that it must, instead of assisting, impede respiration, and at last destroy it ; or that, if it passes and re-passes with inspiration and expiration, that then it is entirely useless ; and after this, that the experiments which the doctor has made, quoted and examined, will not warrant the inferences which he has drawn from them.

First then, if air passes thro' the lungs, into the cavity of the thorax, and remains there, it will expand every way by the heat, and press inward on the external surface of the lungs, which will impede their dilatation, and press outward on the sides of the tho-

rax, and hinder the descent of the ribs; and thus, as more fresh air enters into the lungs, it will be more rarified; and as it is confin'd must at last effectually hinder the lungs from dilating, and the thorax from descending, till inspiration would have been totally prohibited.

To explain this, put a bladder half fill'd with air before the fire; the heat will immediately act, by expanding the air, and the sides of the bladder, which were flabby and lax, will be render'd tight and stretch'd out: in this case, the whole weight of the atmosphere is lifted up, which rested on the bladder, by this rarification from heat, and no power can bring the two opposite sides of the bladder together, during the influence of the heat on the inclosed air, without bursting the coats of the bladder which contains it; in the same manner, the rarified air acting between the lungs and pleura, will hinder the thorax from lessening in its diameter, and the lungs from dilating.

If it should be imagin'd that the weight of the atmosphere might overcome the resistance of this inclosed air, it must be remember'd, that it has no such effect on the distending bladder; and that the doctor himself

self agrees, its weight is but inconsiderable on the lungs, as has been proved.

If you imagine that the air rushing into the lungs imparts a cold to that of the thorax, and condenses it ; by means of which the lungs may dilate, and the ribs descend : this will avail but little also, if you recal how suddenly the air is heated in the lungs, by its almost infinite divisions in the vesicles to the same degree with that within. Thus no argument can be drawn in favour of this inclosed air, from that consideration.

If the second be supposed, which is, that the air passes into the cavity in inspiration, and back again in expiration, it cannot assist either in one action or the other ; but indeed, if it be supposed to enter, there seems no reason why it may not return the same way.

In fact, in all the repeated examinations of the thorax in dead bodies, I have never found one instance, where the lungs did not touch the thorax all round at the first opening, tho' they subsided after, when large apertures were made in the sides between the ribs.

The first experiment which is quoted by Dr. Hoadley in favour of this inclosed air, is that of

Dr. Hales, in his *Hæmastatics*, where he says, after having slit the intercostal muscles of a kitten, he killed it in the receiver of an air-pump; upon dissecting the animal, the lungs were found red, and to have their blood-vessels full of blood: that he kill'd another kitten, without slitting the intercostals; and there the lungs were found white, and very little blood in the vessels. These two appearances, so different from the circumstances of the slit in the intercostals, are assign'd to the air in the thorax pressing out the blood from the vessels in the kitten, which was kill'd without the slit, and the same thing not happening where the slit was made.

But I believe this will not be found any kind of proof of the air's being inclosed between the lungs and thorax: first then, in the kitten, where the wound was made, the intercostals being slit thro' the breast, could no longer be contracted; and thus the lungs always dilating as the air was exhausted, and continuing in that manner, even after the admission of fresh air, there was free liberty for the blood to enter into all the blood-vessels; and this was the reason why
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the lungs were found so red upon dissection; for when the intercostals are slit, the same manner that they acted in, to contract the thorax; must, after the wound is made, dilate it, as shall be prov'd in the examination of Dr. Houlston's experiments.

Secondly, in that case where the intercostals were not slit, as the air was drawn out of the lungs, the intercostals, diaphragm, &c. contracting, because there was no antagonist to them from the dilating lungs; the blood was driven out by their action from the blood-vessels; and therefore they appear'd white.

In the following experiment, where the dilatation of the diaphragm is said to arise from the dilating air, between the lungs and that muscle, the mistake arises from assigning a wrong use to the diaphragm; whereas that muscle being extended by the action of the air dilating the lungs, it was in this instance the same, the air let into the receiver dilating the lungs, distended the diaphragm also.

Thus these two experiments prove nothing in favour of air being enclosed between the lungs and pleura, more than in favour of the manner just assigned.

As to what Dr. Hales has shewn, in his 112th and 113th experiments on the analysis of the air, there is one very material circumstance wanting in the experiment, which is present in nature; and which very probably would have destroyed this phænomenon, which is, that probably the lungs would touch the internal surface of the thorax all round, before any air could pass through the lobes; and in that case, no air could have pass'd through those little apertures, which were found in the lungs in the experiments; because the touching the whole inside by the lungs, would have hindered it, and there would be no space left for it to pass into, the thorax being full.

It is not at all improbable also, that the straining of the dog, when his thorax was opened, had made some little cracks in the lungs, through which the air escaped.

Thus then, in the 112th experiment, there was nothing touch'd the lungs all round to prevent the air's passing, if the holes were natural to the lungs; and lastly, if they were not there in nature, there was no surrounding vessel, which might hinder the lungs from being dilated beyond nature, and thus crack'd by that means.

In the 113th experiment, the aperture which was made suffered the lungs to be distended beyond what they are in nature ; and the convulsions, which must more or less follow such wounds, probably were the cause of those apertures through which the air past.

Thus then no fair inference can be drawn from these experiments, in favour of this inclosed air, because the analogy between the experiment and operation, is not exact enough to suffer such conclusions.

Let us now see if the experiment quoted from Dr. Hales, p. 77. *Hæmest.* and Dr. Hoadley's own experiments, do not prove the contrary to that which he has inferr'd from them, and afford a strong proof in favour of what we have said.

Dr. Hales says, I made an incision of two inches length between the ribs in the thorax of a dog on the right side ; at first opening, the lungs were dilated so as to fill up the cavity of the thorax, for they press'd against the inward orifice of the wound, and continued in this state for some time ; but then as this right lobe of the lungs fell gradually more and more, so the dog shewed more and
more

more uneasiness in breathing, and on dilating and contracting the thorax by the action of the diaphragm, the air rushed briskly in and out at the incision ; but when the orifice was covered by drawing the skin over it, the dog breathed in a natural way.

On straining, the collapsed right lobe of the lungs would instantly dilate so vigorously as to push the lower part of the lobe one or two inches, and sometimes three, out through the incision.

Let us now remark, how the phænomena succeeded each other in this experiment.

First then, the thorax being opened, the lungs were found to fill up the cavity, consequently, there was no air between them and the internal surface of the breast, at that time ; and thus, whatever appearance there might be of it afterwards, it could not be owing to air in the cavity at first, because there was none ; and therefore, this future appearance of it, if there was any such, must be owing to something else, and of consequence, no proof can be drawn from this experiment, for the existence of air between the lungs and pleura.

But

But we shall assign the reason of all the succeeding phænomena, the wound being made between the ribs, of the length of two inches; there was then room for the cold air to touch the external surface of the lungs. This, of course, opposed the dilatation of the lungs by its coldness, and destroyed the rarification of the air in the lungs on that side, in proportion as it was communicated more and more to the external surface of it; thus the power of expansion, by heat, being diminished by the coldness of the air, by degrees the lobe collapsed, the blood-vessels were more contorted, the circulation more impeded; and thus the difficulty of breathing succeeded, and the air rushed into the wound and out again, as the lungs dilated and contracted; but this was the external air of the atmosphere, and not any inclosed between the lungs and thorax: but, upon drawing the skin over the orifice, to cover it, the dog breathed in the natural way; and this rushing in and out of the air was discontinued.

This proves, that the air which past to and fro by the incision, came from without and then returned; otherwise, if the air had
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been within first, and then returned thro' the wound, it is not credible, that the ramification of that air, and the force of the expanding lungs, could have been resisted by the skin of the wound being drawn one part over the other. Surely, it would have divided the lips of the wound, and have made its escape. That animals have a power of distending the lungs, by directing something to that part, beyond what it receives from the rarifying air, is proved by the lungs being forced through the incision, to so considerable a length; and this power is owing to the vital fire, which is determined there by the mind, as has been already observed.

Thus then, this experiment proves, that there could have been no air in the cavity of the thorax of this dog; and consequently, yields no inference, that there is in any other.

The two experiments made by Dr. Hoadley, differ in nothing materially from this made by Dr. Hales; the air that was thrown out at the wound, was always first let in by it: the lungs themselves were thrown out at the apertures, less and less as the cold air entered,

entered, and lessened the expanding power from rarification.

As to the inference, drawn from the trochar's not wounding the lungs when it was thrust into the thorax, that the cavity was not filled by the lobes; a moment's consideration of the form of the instrument, and the direction in which it pass'd, with respect to the lungs, renders it very inconclusive; the trochar, which goes so little beyond the canula, could scarce have wounded the lungs in the oblique direction it was forced, because the point is so quickly formed, after diminishing the circumference of it; and the canula itself forms a kind of shoulder, by which the point is hindered from wounding, unless it be something directly oppos'd to the point of it; and thus it easily pass'd obliquely over the surface of the lungs, without making any wound at all.

As to the more sudden death of one dog than the other, all that difference happened from the different sizes of the wounds; the cold air, by the larger wound destroying the expansive power of the heat much sooner in the lungs of that dog where the large wounds were made, than in that where they were less,

less, because there was more of it admitted; and, consequently the power of dilating the lungs by the air which entered by the wind-pipe, was much sooner taken away.

As to that force which was exerted on the trochar in the thorax, and which made it so difficult to keep it in, supposing air to be the cause of it; the wound which let in the trochar would let in the air with it; and then it was no wonder that it should act upon the instrument, when it was rarified, and force it out.

But give me leave to say, that it is by no means necessary, that the force which makes any thing rush forward, should act in the direction of its length, on the end of it; a very different direction of power will produce this effect, where the thing operated upon is held steady by any means, as in the instance of a ship held steady by the rudder, where it is pushed forward by a side-wind, in a line very different from the operating cause; and in like manner, the trochar might have been pushed out by the lungs pressing on the side of it; and, when the trochar was withdrawn, the canula suffered the cold air to
enter

enter more freely, which checked the expansion of the lungs in that lobe: and thus, according to the different quantities of cold air let into the thorax of the dogs, did they live longer or shorter.

There is one thing which appears somewhat singular in Dr. Hoadley's reasoning upon the experiment made by Dr. Hales, where he says, agreeable to this, whilst the orifice was open, the dog breathed with difficulty, because in inspiration, when the air in the cavity should have been rarified, the external air rushed in through the wound, and prevented it. Now, according to the properties of air, hitherto known, these two circumstances of the air's being rarified at the time of inspiration, and rushing into the wound at that time also, could not possibly have happened.

First then, the air, supposing there was any in the cavity, could not have been at any time rarified during inspiration, unless cold rarifies, and heat condenses; for certainly the cold air entering into the vesicles of the lungs, must communicate some degree of cold; however little it may be supposed, to the air in the cavity: and therefore this
air

air must be more condensed at that time than during expiration, when the air which was heated by the lungs returned through the wind-pipe, and no cold is communicated to that in the cavity.

Next, if the external air rushes in through the wound, between the ribs, during the action of inspiration, it must move upon principles hitherto undiscovered ; because the air in the cavity will be press'd to the aperture of the wound by the expansion of the lungs, and rarified air is always passing off by every possible passage ; and therefore, air cannot enter during the time of inspiration. If what is here said be right with respect to the air in inspiration, what Dr. Hoadley has said on expiration must be erroneous, because it is the reverse of this ; and indeed, it seems to me, that what he has supposed could happen in inspiration, must be the case in expiration, and vice versa, and the believing that the skin of a wound drawn over the other side, can keep in rarified air, is somewhat strange, when one considers the force and effect of rarified air.

Thus then we may conclude : First, that the actions of the intercostals, both external
and

and internal, diaphragm and serratus posticus inferior, act only to depress the ribs in the time of expiration.

Secondly, That the dilating air and vital fire, directed to the tunica cellularis in the lungs, are the only active powers in inspiration.

Thirdly, That the cavity in the thorax is always lessened by the action of the intercostals and diaphragm.

Fourthly, That the enlarging the cavity is designed only to contain the inflated lungs, which, in all the times of respiration, are contiguous to the pleura, to permit a free circulation of the blood through the vessels, by making their directions less contorted; and to furnish air for the use of language, and other uses already mentioned. And thus it appears impossible, that the intercostals can have two different actions, or either of them elevate the ribs; that the diaphragm can assist in the action of inspiration; or that air can be inclosed in the cavity of the thorax.

C H A P. VII.

Of the motion of the Stomach, and Intestinal Tube.

FROM what has been said on the manner in which vital fire acts on the heart and arteries, it will be easy to conceive what passes in the stomach, from the same power ; and first, the stomach must be dilated from every explosive effect of this vital fire, acting on the fluid in the tunica cellularis; and of consequence contracted alternately by the elastic force of its muscular fibres; the intestines, like the arteries, will be dilated by every accession of this vital fire, and be contracted by their muscular fibres also; and thus the motion of the stomach and intestines, is easily accounted for, whenever it takes place.

But from some experiments which I have seen made by the Pere Bertier, of the academy of sciences at Paris, there is reason to believe that the peristaltic motion of the intestines does not take place but on extraordinary occasions, when the tube is of-

fended with some matter which stimulates it.

The experiment which has been very often repeated was this : he made a large opening in the side of a dog's belly, and then sew'd on to the skin a transparent piece of horn, prepared for that purpose ; after this, we observed, with the greatest attention, whether there was any peristaltic motion in the intestines, and during an hour's observation, there was not the least appearance of any thing like it in the intestines. After this we fed the dog, and observed at different times, whilst the aliment was passing through the canal, and yet there was no motion at all of that kind ; having observed this, we mixed a purgative with his meat, and during the time that this was passing through the intestines, the peristaltic motion was very visible.

It seems then probable, from this experiment, that the peristaltic motion is not natural at all times, and only design'd to carry off whatever may offend nature more expeditiously than otherwise it would have been done.

And indeed, when one considers that in persons, who are regular and healthy, the

ingesta are voided by the intestines but once in twenty-four hours, that a small purgative will accelerate that discharge, and pass thro' the whole tube in less than an hour ; it seems probable, that the peristaltic motion is not exerted in the intestines, but on occasions where something offends them.

It is very probable, that the action of the lungs on the diaphragm, by pushing it down, which indeed is another use of respiration, and the abdominal muscles acting alternately against each other, are sufficient to answer all the common force and mechanism, for emptying the stomach and intestines.

C H A P. VIII.

Of the Erection of the Penis.

IT has been generally said by anatomists, that the erection of the penis was owing to the blood passing thro' the arteries into the cells of the corpora cavernosa, and hindered in its return by the veins ; and this account has been credited, because injections thrown into the artery, easily pass'd into the cells of the corpora cavernosa : but this, though it proves that some particular injections will pass that way, by no means proves that the blood will, because the arteries let a thinner fluid transude through all their sides, without suffering the blood to pass that way : and thus it probably happens in this instance also.

But, in imagining that the blood is the cause of the erection of the penis, there is yet no reason assigned why the penis is not always erect, or when it is, how it becomes flaccid after it ; why does the blood pass through at some times, and not always : so that, in saying the blood is the cause of this

erection, without saying how, is no explanation of the thing.

And here, I believe, a farther proof of the vital fire's acting in the manner it has been explained, may be gathered.

The mind then being incited from health, from love, or from whatever cause it may be, to the act of venery, the vital fire passes to the corpora cavernosa penis; and there distends the cells in the manner in which it is found, at the time of erection. Now, if the blood passes into the corpora cavernosa, it must be by means of this vital fire first distending these cells, otherwise it would always pass; but I believe, that it never does pass at all, and the whole distension is owing to this vital fire.

And this may give some explanation of the reason for that old saying, *Omne animal post coitum triste est*; the vital heat, which, as has been explained, is the cause of motion, being diminished by the vigour of this action, which demands more than the common offices of nature; there succeeds for a few moments a small faintness about the heart, and a dejection, from the want of a sufficient quantity of this fire, to give it the usual dilatation.

And this also will assign some reason, why the repetition of the venereal act depends on the health and vigour of the person; and why it cannot be repeated at libitum. viz. The vital power being too much exhausted, and the fluid in the cells of the corpora cavernosa dissipated by the repeated action; and both these are in proportion to the state of health.

Thus it may be easily conceived how the corpora cavernosa become distended at certain times, and the penis erect; and how at other times it becomes flaccid, by means of the presence or absence of this vital heat.

C H A P. IX.

Of the Motions of the Iris.

IT does not yet seem to be perfectly agreed amongst anatomists, whether the iris be composed of two sets of fibres, the orbicular and radial, or of either.

However, though Haller denies that he ever could discover the orbicular even with a microscope, in the iris of an ox, yet he is by no means so positive in denying the existence of the radial; indeed, the last seem visible to the naked eye, and easily demonstrable.

Now these last fibres are sufficient to answer all the purposes required in the motion of the iris, either for the dilatation or contraction of the pupil, or, which is the same thing, augmenting or diminishing the breadth of the iris; and this is farther to be remarked, that though the orbicular fibres should be granted to exist, yet they must have a different effect in their being acted on from what has been hitherto assigned them by anatomists, and have dilated the pupil, and not

con-

contracted it, for the same reason which has been given in explaining the motion of the arteries ; but, as the contraction and dilatation of the pupil may be perfectly well performed by the radial only, it seems altogether useless and inconsistent with that intelligence, which appears in the formation of all the other parts, to imagine there are any.

Let us suppose those radial fibres of the iris, analagous to all the other fibres of the body, are surrounded with the tunica cellularis, at every act of volition which determines the vital fire to those vesicles, the same effect will succeed which takes place in muscles fastened at one end only, for the fibres are hindered from retiring into the tunica albuginea ; thus then every dilatation of the vesicles in the cellular membrane, must increase the breadth of the iris, which is the same as lengthening the radii of the radial fibres ; and thus the pupil must be diminished : and this is the action which answers to the exertion of the will on the eye, and upon the intermission of volition, the elasticity of the fibre takes place, and the pupil is dilated and each radial fibre shorten'd. And thus, according to the different degrees of vital fire deter-

determined to the iris, the pupil will be either greater or less.

Thus it seems to me, that the cause of animal heat and of vital motion are sufficiently explain'd, by the action and effect of vital fire, and the elasticity of the muscular fibre operating alternately in the animal body.

Now, tho' the manner in which vital motion is accounted for, and the cause of vital heat are different from whatever has hitherto been assign'd by physiologists, yet I believe the more it is examin'd into, the less objection will be found to lie against it.

One thing it has in its favour above the preceding accounts, which is, that thro' the whole of it there is nothing supposed, no property assign'd either to fire or elasticity, no new formation given to any part of the animal body.

We require no more of the nerve than that it exists, which no one denies; that it is the conductor of heat, experiment proves to us: we ask for no visionary fluid, either denominated animal spirits or æther, nor elasticity in the nerve, which experiment proves it has not; we require no vesicles in the
muscular

muscular fibres, but we affix a use to the tunica cellularis, hitherto unknown and unaccounted for.

We have another thing in our favour, that vital heat and vital motion are here as they are in nature, beginning together, and continuing so thro' life; the action of each is more simply explain'd than it has hitherto been done, and all the seeming contradictions between the action of muscles solid and fix'd at each end, and those which are hollow or fix'd at one end only, are reconciled from their different form and mechanism.

In short, this way which nature follows in producing vital motion, has been discover'd and applied by men to machines, at least to one, tho' it has been altogether undiscover'd with respect to the animal frame; it is analogous to that mechanism which is in the engine which draws water out of mines by means of fire, rarifying water into steam.

In this case, the rarified vapour operates against the weight of the atmosphere, and the atmosphere reacts in its turn, when the vapour is condensed into water, and the
piston

piston descends into the vacuum in the cylinder.

There is nothing more requir'd to make these things similar, than to place the elasticity of the fibre in the stead of the weight of the atmosphere, which is done every day in watches and clocks, where an elastic spring effects in some machines what weight does in others, and the effect will be the same, the explosive or dilating power being the same in the engine, where fire acts upon the water, by repelling its particles, and forming a vapour; or in nature, where it effects the same thing in a lesser degree, on the fluid in the vesicles of the cellular membrane.

In the first, the vapour is condensed by cold; because the heat cannot pass off sudden enough with the vapour thro' the cylinder; and thus the atmosphere presses on the piston, and makes it descend.

In the second, the heat passing off with the fluid thro' the skin, and acting by pulsations or intermission, the elasticity of the fibre finds time to operate; and thus motion is continued in the machine, and in the animate body.

C H A P. VIII.

An Examination of the Experiments which have been brought to prove or confute the accounts which have been founded on animal spirits, &c. to see how far they are applicable to prove the truth of what has been advanc'd already.

IN the preceding chapters, having endeavour'd to ascertain what vital heat is, and how it operates to produce motion voluntary and involuntary in the animal body, it may not be amiss to examine how far the experiments which have been made to support or contradict the hypotheses of other physiologists are reconcilable with, or contradictory to what has been said by us. At the same time to see, whether the manner in which nature is said to operate in these sheets, is not capable of being prov'd the true one, from observations which hitherto have been little attended to, and yet are of great consequence in the decision.

First then, let us examine those experiments which have been made on the nerves, to prove, that the cause of voluntary motion

in the muscles, arose from animal spirits passing thro' them, from an æther, or elasticity in the nerve itself.

The division of the nerve which goes to any particular muscle, is known to destroy all motion in it, and render it paralytic.

This then proves no more to support the existence of animal spirits, æther, or vibration, than it does its being the conductor of vital fire; the same division which destroys the effect which might be imagined to rise from the former, will effectuate the same in the way we have shewn it to operate; the vital fire can no more be carried to the tunica cellularis in the muscle, when the conductor is divided, than either æther, animal spirits, or vibration perform'd by it, after the continuation of it is destroy'd. If a nerve which leads to any muscle be tied with a thread, that muscle will become paralytic. This experiment, as it cannot destroy vibration, nor impede the passage of æther, was consider'd as a proof of the existence of animal spirits; but as the size of the nerve did not increase above the ligature, this brought the belief of animal spirits again into doubt.

For this reason, Mr. Monro, after having fix'd a ligature upon the phrenic nerve above the diaphragm, and by that means rendering it paralytic, when he strok'd the nerve from the place where it was ty'd downwards, he put the diaphragm into action, by the passing his fingers along the nerve from above downwards.

This experiment induc'd him to believe, that by thus pressing the nerve, the animal spirits were driven into the diaphragm, and thence the action was communicated to that muscle; but, in fact, if he had began from below, and stroked the nerve upwards, the effect would have been the same, as it has happen'd in the trials which I have made.

Thus then, this experiment being at best but problematical, and no plain proof of the existence of animal spirits, in the producing animal motion, let us see if the effects of this very experiment may not be better accounted for from the properties of fire, the cause of the palsy attending this muscle after ligature, and the motion which is communicated to it by the stroking of the fingers, better ascertain'd.

It has been long known from experiment, that the conductors of fire from the electrical machine, if they are suspended by other conductors of this fire, will carry it off at those places where they touch, by which means it will be discontinued thro' the line you intended it, and be dissipated by those other which supported the first.

Is it not probable, that the very same effect is produced by the ligature, in the instance of the nerve being ty'd, and the muscle depriv'd of motion; the ligature effects the same thing which the conductors in the other instance of the experiment did; and thus the fire, which should have been continued thro' the nerve to cause motion, is carried off by the ligature, and the muscle render'd paralytic.

If it should be objected, that the ligature being made of silk, that the fire would not have been conducted by it; it must be remember'd, at the same time, that the silk in this case must be moist from its situation, and that then it is equally a conductor with vegetable substances.

This then, will offer some account for the palsy attending those muscles below the ligature, after having been ty'd.

What adds a considerable force to this argument is, that a substance so subtle and pervading as the animal spirits, can scarce be prevented from passing along the nerve by a ligature, especially as there appears no swelling above the ligature.

This then seems to offer some reason for the muscular motion being destroy'd after the ligature was made; but how will it assist us in explaining the cause of the returning motion of the diaphragm upon the nerves, being strok'd with the fingers?

To do this, let us describe an experiment made by the Pere Bertier, whose name has been already mention'd in these papers, and give an account of what was the consequence of it.

He placed upon some supporters of wood a bell-glass, in such a manner that his hand might easily pass under it: within side this glass, from the center in the top he suspended in æquilibrium a thin piece of pasteboard, or a small wire, by a silk thread fasten'd to the middle of the glass, by means of some sealing wax; then putting his hand under the glass, he found that his fingers attracted those substances very strongly, and at con-

siderable distances ; if he presented any other thing, he found that the pasteboard or wire were attracted by it, but not equally strong as when his finger only was presented to it. He found also, that with his finger moved outside the glass, that the suspended substance was attracted to some degree.

The design of the bell was to hinder all interruption from the motion of the air, or breath of those who were present ; this experiment then offers a proof, that the animal body is always sending off the vital fire thro' its pores ; and the experiment made by Mr. Watson proves, that as it passes from animals to any other substance, it enters into them from the earth : thus it is constantly giving and receiving.

This phenomenon then, will assist us in explaining the reason of the motion which return'd to the diaphragm, upon the phrenic nerve being either stroked upwards or downwards : during the time that the fingers were applied to the nerve, that vital fire which was carried off by the ligature, was supplied below it from the touch of the experimenter ; and thus the muscle was again put into motion.

Agree-

Agreeable to this, the punctum saliens in the chicken was recover'd to its pulsation by the application of a finger, as it is mention'd by Dr. Harvey in his Exercitatio, 17^{ma}.

Ovo insuper aeri frigidiori diutius exposito, punctum saliens rarius pulsat, et languidius agitur: admoto autem digito calente, aut alio blando fotu vires statim vigorem recuperat. Quinetiam postquam punctum hoc sensim elanguit, et sanguine plenum a motu omni cessans nullum vitæspecimen exhibens, morti penitus succubuisse visum est: imposito digito meo repente, spatio viginti arteriæ meæ pulsuum, ecce corculum denuo reviviscit, erigitur, et tanquam postliminio ab orco redax, pristinam choream redintigravit. Idque alio quolibet leni calore ignis nempe, aut aquæ tepidæ, iterum iterumque a me, atque aliis factitatum est; ut pro libito, miscellam animam vel morti tradere, vel in lucem revocare, in nostra potestate fuerit.

This experiment is a most certain proof of the effect of heat being sufficient to create the difference of life from death, of motion from rest; and it offers another proof, which was unobserv'd by this great genius in physic, perhaps the greatest which this island or

any other part of the world has produc'd, and which is, that when the heart began to vibrate, the diastole was its first motion, and then the systole succeeded; and this adds great credit to the reason we have assign'd for the vital fire acting in the manner we have ascertain'd it.

Thus then you see how heat added to an animal, whose fibres are easily acted upon, may recal motion; and perhaps, in another instance, amongst vegetables, by a contrary effect put them into motion; for example, where the sensitive plant is distended by the vital fire which is in it, the touch from an animal, or any thing giving a sudden discharge to that explosive power which lodges in that part of it which answers to the tunica cellularis in animals, the fibres corresponding with the muscular also are put into action, the equilibrium being destroy'd between the extending and contracting powers: and thus that shrinking away, and almost animal motion, is perform'd.

It has been found, that if a ligature is made on the nerve which is called the par vagum, that the heart is thrown into convulsions by it at first, and after some time becomes paralytic.

These effects seem to arise from this, that the vital fire being conducted to the heart by other nerves, as well as by the par vagum; after the ligature is made on this last, there yet remains enough, conducted by the other nerves, to cause the irregular motions which are convulsive for some time, tho' not enough to sustain that regular one which is natural to it; till at length the fibres, by their native elasticity over power the explosive force which is imparted to the tunica cellularis of the heart, by those nerves which remain without ligature; and some part of the tunica cellularis, by means of the ligature on the par vagum being unsupplied with this vital fire; at first there succeeds an irregular, and then a cessation of all motion. Instead of making a ligature on the par vagum, which hinders the influx of vital fire thro' that conductor into the heart, if we should make one on the vena cava, and prohibit the blood from entering into the ventricles of the heart, these ventricles will still continue to dilate and contract; which is a clear demonstration that the diastole of the heart does not arise from any impulse communicated to the blood; because, at this time, there is no

blood that enters into it, as has been said by Dr. Simson ; nor can the systole arise from any stimulus in the blood, as has been imagined by Dr. Whytt and others, for the same reason ; because nothing can act where it is not : and therefore the blood cannot be the cause of the systole.

If you render a limb paralytic by a ligature on the nerve, and do not continue this ligature any long time upon it, upon taking it off the palsy will cease, and the muscles recover their motion.

The reason of this seems to be, that the tunica cellularis not having its vesicles clung together from the want of the expanding fire, by an interruption of it from the ligature, it recovers its use as soon as the ligature is taken away, and the fire again conducted thither ; and thus motion is again communicated to the limb : but if the ligature be long continued on the nerve, the vesicles of the tunica cellularis which depend on it, or are an expansion of it, become stuck together and inseparable ; and thus all motion destroy'd in those muscles forever after.

A muscle put into motion by the will, may yet be more actuated by a farther extension
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of volition, as from walking to running: by this operation of the mind, there is more of the vital fire determin'd to the muscles employ'd in those actions, and muscles are brought into action by the shock of fire passing from the electric machine, and palsied limbs have been render'd plump by this fire communicated to them by the same machine, and a power of motion and action restored to those whose palsies have not been of long standing, and which did not take the source from the spinal marrow. This seems to offer a very convincing proof, that vital fire is the cause of muscular motion, and that this vital fire is the same with that which is collected by the electrical machine.

The heart of a viper or of an eel, taken from the body of those animals after they are dead, if you apply heat to it greater than that of the atmosphere, either by means of water, or by any other method, it will again begin to vibrate. Now heat is fire, and thus you see the same effect is produc'd in the same organ of an animal, whether dead or living.

The secretion in the tunica cellularis will still be influenc'd by the force of fire, and the vesicles distended whilst that fluid continues unevaporated, and the muscular fibres are not become too rigid by cold to be put into motion by this fire.

The reason why the hearts of vipers, eels, and such like animals, are put into motion by a power of the same nature, tho' in a less degree than that which moves the hearts of greater animals is, that being extremely cold by nature, a less degree of fire actuates on their hearts, and thus the fibres are purposely more delicate and influenc'd by a less degree of fire; the same degree of heat which is necessary to keep a fowl alive, would certainly destroy a frog or viper, and burst the cells of the tunica cellularis, or at least keep them so distended, that the elasticity of the fibre could not re-act against it.

Unless the fibres of the heart were made thus delicate, and easily put into motion, those animals which sleep all the winter could not so easily be brought into life and motion from such a state of lifeless inactivity, by so little a degree of heat above that in which they sleep.

After

After the heart of a viper has discontinued to beat with the application of any certain degree of heat, it will vibrate again, when a superior degree is applied to it; as a heart that has ceased to beat from warm water will yet perform the motions of diastole and systole, by the bringing a hot iron near it.

The heart which, in the exhausted receiver of an air-pump, vibrated again with the same heat, after it had ceased to move in the open air, beat from this: the weight of the atmosphere being taken off from the surface, a less power was required to distend its fibres, when the weight of the atmosphere no longer press'd upon the heart. Thus the vesicles of the cellular membrane extended the fibres, and those again in return acted with more facility.

The person who was so long apparently dead, mentioned in the Medical Essays of Edinburgh, and was recalled to life again, if we give the least attention to the manner in which it was done, we shall find that the breath which was blown into his lungs, was warm from those of another person; and consequently the heat past by the nerves from the lungs to the heart, and recommenced its vibrations; besides this, the friction

tion by which the body was put into an attractive state, and drew fire from the earth.

It has been observed, that the right ventricle and auricles still continue their pulsation, after the left have ceased to move; and that the right auricle beats, after the ventricle on that side has discontinued its motion. A slight consideration of the fabric of those parts, will offer us a reason for it; the left ventricle and auricles being stronger than the right, that is, having more fibres, and those more rigid than the other, it requires the exertion of more fire in the tunica cellularis, to put them into motion, than in the right; and thence the right ventricle continues to perform its diastole and systole, with much less power of fire than can effect those motions of the left, and pulsates after the others are at rest. The same thing happens to the right auricle, compared with the ventricle; a less expanding force of vital heat continues its motion, than is required for the ventricle.

The heart of a viper, eel, or other cold animal, after it is taken from its body, will still beat for some time, if it be touch'd or prick'd by a needle or pin.

If

If we recollect the Pere Bertier's experiment, that the vital fire is continually passing from us ; that the suspended paper was influenced also by any thing presented to it, though not so strongly as by the naked hand ; that a very small degree of fire above that in the atmosphere suffices to put the hearts of those cold animals into motion, as is proved by the slight alteration in the atmosphere, which calls them from death to life, from rest to action ; that all pointed objects carry and communicate this vital fire more strongly than others, we shall be no longer under any difficulty to solve this phænomenon of vibrating from the prick of a pin, the vital fire passing from us to them ; and thus, whilst the fluid in the cellular membrane continues fit for expansion, and the fibres are not become too rigid by drying, the action of diastole and systole will be continued, and thence the hearts of those animals continue to vibrate.

The experiment of the tortoise living so long after decollation, perhaps may be accounted for from the vital fire continuing to operate in this manner,

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The tortoise is that kind of animal whose nerves take their source chiefly from the spinal marrow ; thence it follows, that in cutting off the head of this animal, the nerves, which are conductors of the vital fire to the heart, are not destroyed, nor is the effusion of blood considerable enough to lessen the quantity ; so that the circulation cannot be continued : by this means the animal still drawing the vital heat from the earth, continues to live, and would still live, if the eyes which serve him to seek his food, and the mouth to gather it, were not cut off in the head ; for in fact, these two last mentioned circumstances excepted, it is no more to be wondered at that the tortoise lives without a head, than a human creature, or quadruped, without a leg ; the principles of vitality of the former animal being no more placed in the brain of it than it is in the legs of the latter :

Perhaps also, this way of explaining animal motion, may offer a solution to that difficulty of accounting for the life of animals, after the ossification of the brain.

In that account of the ossified brain of a cow, given by Dr. Simpson, I find that there
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are physicians who have doubted its being a real ossification of the brain ; and indeed, from the doctor's own account (the evidence apart, which he brings of it) I should be inclined to believe the same thing ; he says, " What I take to be the cerebellum, is indeed " six times at least bigger than the natural."

And this indeed, would naturally incline one to believe, that this substance was not a real ossification, because the truth of it depending on its resemblance to nature, and that being destroyed by this præter-natural appearance, as well as no notice being taken of the different formation of this cow's head from that of others, we should be inclined to believe that this was not a real ossification of the brain, without the evidence of the people who were present.

Nor is it said whether this ossification had its middle part in its natural state, or not ; nor how the nerves appeared which went from it.

However, supposing all that can be desired, that this is an ossified brain; as in the manner we have accounted for vital motion, the power we have assigned for the cause of it is not generated in the brain, the ossifica-
tion

tion offers nothing to contradict it, because that may continue to the nerves the fire that is drawn from the earth ; and thus this phenomenon receives a more probable explanation than has hitherto been given to it.

In the same manner monsters which have had motion imparted to them in the womb, tho' differently organized from nature, without mouth or stomach, for example, will continue to support this motion, by the means of attracting fire from the earth, till through the want of fresh supply of aliment, which is to afford the crassamentum of the blood, and which is the attracting power, there is no longer a sufficient quantity of fire drawn from the earth to sustain life and motion ; and thus they die.

Will not this manner of explaining things afford us some reason for the polype continuing to live and propagate after being cut into pieces, or turned inside out ?

This animal then must, from the very circumstance of living, and performing the offices of life belonging to it, when it is cut into pieces, and turned inside out, be the least organized of all animal bodies which have been hitherto discovered; it may be com-

pared to a gut which is the same from one end to the other.

Now dividing this animal so form'd, does not separate one part which is vital from another which is less so, but the same manner of formation continuing thro' the whole, every separation leaves as entire an animal as before; as every section of a tube is as much a tube as the whole : thus then, no vital part being separated by the cutting, the parts thus divided continue to draw that fire, which is necessary for this inferior degree of vitality, and each division continues to shoot out new ones, as a piece taken from horse-radish root will shoot forth new roots and leaves, upon being planted.

It is a little surprizing, that after it was known that the destruction of the cellular tunic in a muscle was always attended with a depravation of motion in that muscle, that the real use of this membrane should still have continued undiscovered ; what can possibly give a greater proof of the use of it in muscular motion than the loss of motion by the destruction of it, and what more probable use can be assigned to it, than what has been attributed to it in the foregoing parts of this essay.

To see what effect the fire, which is collected and distributed by the electrical machine, would have on the heart of an animal, I took the heart of an eel, which had been some time dead, and placing it on a card, then put it on the electrified bar of iron ; the first motion which was communicated to it, was its swelling or the diastole of the ventricles, which not being immediately followed by the contraction or systole, I applied my finger, and drawing an electrical spark from the heart, it contracted, and performed its systole ; then it dilated again, and upon application of my finger it again contracted ; and thus, having repeated it several times, the heart continued to perform its diastole and systole, without being touched ; and when it was removed, it ceased moving, and began again upon being placed on the bar.

At the first putting it on the bar, it is probable that the fluid in the vesicles of the tunica cellularis, could not get through the pores to carry off the electrical fire ; and thus the heart continued distended ; but the spark being drawn off by my finger several times, the fluid found its way through the vesicles, and the elasticity of the fibres taking place, it performed its diastole and systole.

In this case, as in that of the punctum saliens in the foetus of a fowl, the diastole began first; and thus it always happened upon every application of the heart to the electrified bar.

Another proof of the heart's being inflated by some power, which moves it with quickness and force, is this stroke, which it gives with its apex against the left side of the breast.

It has been said by Dr. Senac, physician to the king of France, in his Treatise on the Heart, that the stroke against the ribs, arose from the following cause:

The blood, says he, which is thrown out by the heart in every pulsation, is like all other projected bodies, endeavouring to go off in a strait line; but as the curves of the aorta hinders this inclination by the resistance which is given to it by this figure, it must naturally re-act to the impulse of the blood; and thus consequently touch up the apex of the heart, and make it strike against the side of the thorax.

This, however plausible it may appear, cannot be the true cause of it, because then this stroke must be during the systole of the ventricles, which would also be synchronous

with the diastole of the arteries, whereas the beating of the heart precedes the dilatation of the artery, and thence this stroke must be made during the diastole of the ventricles: thus the diastole or distension of the heart is the cause of this beating against the ribs.

Indeed, whoever considers the situation of this muscle, and the power which has been assigned for its dilatation, will be under no difficulty of conceiving that it could happen at no other time but during the diastole of the ventricles.

Winflow, the most exact anatomist, perhaps, that has been known, describes its situation thus, and which will appear true to all that shall take pains to examine it. Speaking of the heart, *Il est presque tout a fait tranversalement couché sur la diaphragme, sa plus grande portion avance dans la cavité, gauche de la poitrine, et sa pointe est tournée vers l'extrémité opposée de la sixième vraie cote.*

Being thus placed, the sudden dilatation of all its parts from any power will naturally lift up the apex, as the side rests on the diaphragm; and thus consequently strike it against the side of the thorax; and probably this little inclination of the apex to the left side rather than pointing from the middle, is
ori-

originally owing to the left ventricle being formed with stronger fibres than the right ; and thus, in its tender state, the heart being unequally agitated, that is, the left side being contracted more than the right, that little inclination of the apex has risen from that cause.

Another reason why the re-action of the aorta upon the heart cannot produce this striking against the ribs, is this : if this re-action takes place at all, it must act directly answering the curve of the aorta ; and thus it would not act on the apex at all, because the aorta running down the spine of the back, the effect of its re-action would be diametrically opposite to that which would be in the middle of the sternum ; now the apex lies at an oblique direction from the aorta on the left side, and thus will not be influenced by this re-action of the aorta.

Agreeable to this manner of thinking, in that very singular case related by the great Harvey, in his 52^d Exercitat. it was found that the stroke against the breast was, during its diastole.

Simul cordis ipsius motum observavimus ; nempe illud in diastole introrsum subduci et retrahi ; in systole vero emergere denuo,

& protrudi fierique in corde systolen, quo tempore diastole in carpo percipiebatur : atque proprium cordis motum & functionem, esse systolen : denique cor tunc pectus ferire & prominulum esse, cum erigitur sursum & in se contrahitur.

Thus you see, from this description, that the apex of the heart being lifted upwards by its dilatation above the wound, appeared to be drawn inward in its diastole, and when that power ceased then it came lower, and appeared extended in its systole; but that it was not really shortened by the diastole, the effect which it had in striking the side will convince us; for at that time, by the above account, the stroke happened; and thus it was lengthened and extended every way; and all the phænomena in this account arise from the situation of the wound being opposite to the apex, and are explicable from what has been said on the cause of vital and involuntary motion with respect to the heart, and gives a very extraordinary proof of this stroke being at the time of the diastole of the ventricles.

That Harvey saw the dilatation or diastole of the heart was prior to the systole, we have but to quote his own words in his 51st Exercitat.

Hinc quoque apparet sanguinis principalitas quod pulsus ex eo ortum ducat, cum enim duæ sint pulsationis partes ; (distentio nempe & contractio sive diastole & systole) horumque motuum distentio prior sit ; manifestum est, actionem illam sanguini competere : constrictionem vero, a vesicula pulsante in ovo, (ut a corde in pullo) propriis fibris instituti tanquam ab instrumento ei usi i destinato. Certumque est vesiculam dictam, ut & cordis auriculam postea (unde pulsatio primum incipit) a distendente sanguine, ad constrictionis motum irritari, fit, inquam, diastole, a sanguine ab interno quasi spiritu intumescente : adeoque Aristotelis sententia de pulsatione cordis (fieri eam scil. ad motum ebullitionis) aliquatenus vera est, quod enim in lacte ab igne calefacto, & cerevisiæ nostræ fermentatione quotidie cernimus ; idem etiam in pulsu cordis usu venit in quo sanguis, quasi fermentatione aliqua turgescens, distenditur et subsidit ; quodque in illis per accidens, ab agente externo (calore scil. aliunde adventitio) contingit : id in sanguine, ab interno calore, sive spiritu innato efficitur, idque etiam secundum naturam ab anima regulatur.

In this paragraph then, is accurately and plainly described the motion and phænomena of the heart, its diastole is shown to be the first action; and systole, by the contraction of the fibres, the consequence of it; and though the true cause of these phænomena are not assigned, nor in what manner, or what is the operating power in these motions, as has been already proved in refuting the doctrine of intestine motion, in the account of Dr. Stevenson, yet the description of the heart in the diastole and systole answers exactly to the appearance which it has in these actions, quasi spiritu intumescente, in its diastole; and to me it appears evident, that if the same experiments had been made on fire in Dr. Harvey's time, by the electrical machine, which have been made within these few years; and the parts of the body then so well known as at present, the true cause of vital heat and vital motion had been by him discovered and explained.

Give me leave here also to observe one thing, which cannot escape the remark of any one who reads Dr. Harvey with attention, which is, that Dr. Stevenson, in his essay on animal heat; Dr. Whytt, and Dr.

Simson,

Simson, in theirs on vital motion, have all three borrowed their accounts, without confessing it (for they all appear to have read Harvey) from their works; and perhaps, from the last paragraph, where these words will give us the first idea of Dr. Stevenson. Adeo Aristotelis sententia, de pulsatione cordis fieri eam scilicet ad modum ebullitionis aliquatenus vera est, quod enim in lacte ab igne calefacto, & cerevisiæ nostræ fermentatione quotidie cernimus, idem etiam in pulsu cordis usu venit: in quo sanguis, quasi fermentatione aliqua turgescens, distenditur et subfidit: quodque in illis per accidens, ab agente externo (calore scil. aliunde adventitio) contingit: id in sanguine, ab interno calore, sive spiritu innato efficitur. And this, I think, sufficiently shews us, where the idea of the intestine motion of the particles of the blood, as the cause of heat, took its rise.

And it is yet plainer, that Dr. Whytt's account, together with Haller and others, came also from this source, where a stimulus in the blood is assigned as the cause of the systole of the heart: Certumque est vesiculam dictam ut et cordis auriculam postea [unde pulsatio primum incipit] a distendente sanguine

sanguine ad constrictionis motum irritari. Which surely is the passage from which all the physiologists who assign a stimulus, as the cause of the contracting heart, have taken their first idea; and the sentient principle takes its rise from those words below : *Idque etiam secundum naturam ab anima* (translated sentient principle) *regulatur et in salutem viventium continuatur.* Thus, all that Dr. Whytt has said in his whole book, is to be found in this paragraph.

As to Dr. Simson's account of the blood passing from the veins, and thus distending the ventricles of the heart, that thought is clearly expressed in these words : *Cum enim duæ sunt* (pulsationis partes ; distensio nempe & contractio, sive diastole, & systole) *horumque motuum distensio prior sit, manifestum est, actionem illam sanguini competere.*

And thus indeed, it must appear to the eye that beheld the blood entering into the ventricles, as Dr. Harvey did in the fœtus of a chicken, and who had not at that time, sufficient experiments on the effects and operation of fire, nor the fabric of the heart well enough understood, to explain the cause of the diastole.

Thus

Thus then the cause assigned in this great author, for the vibration of the heart, arises from the *callidum innatum*, or vital heat, though he appears intirely a stranger to the manner in which this heat was attracted and continued ; and the motions of the heart are exactly and truly described, in their true succeffion to one another : and though he has not conceived, in any manner, how the diastole was performed, or how this vital heat acted on the mechanisim and parts of the heart, yet he plainly saw the true cause of the systole *constrictionem propriis fibris institui* ; that is, by their own elasticity.

Thus it is evident, that all those who have taken their first thought from him, either of vital heat or vital motion, have not one jot advanced the explanation of its cause or operation ; but touching only the periphery of his divine imagination, have been whirled by its motion, like drops of water from a wheel swiftly turned centrifugally from the truth.

Indeed, it adds no little confidence in me of the truth of the account which is assign'd as the cause of vital motion, that the phænomena of the heart, in its diastole and systole,
answer

answer exactly to the influence which the vital heat must have upon that muscle, as they are described by this great man, and laid down in the previous chapters.

There is one thing which flipt me in accounting for the diastole of the heart, which is, that during the dilatation, when the blood enters the ventricles, the coronary arteries receive that fluid, contrary to all the other arteries of the body ; and thus supply the body of the heart with blood, and perhaps, this blood is partly the cause of the vital heat being attracted stronger into the heart by the nerves at that time, than any other ; though there is another reason for its passing at this time rather than any other, which is, that the passage of the blood is freer through the arteries during the heart's inflation, than at the contraction, because those vessels then approach nearer the direction of a strait line.

This way which I have explained the motion of the heart, will solve the difficulty of accounting for the circulation of the blood being continued when the auricles and sometimes part of the ventricles of the heart have been offixed ; whereas, in placing so
great

great a force in this viscus, as all other physiologists have placed, it is next to impossible that a muscle so changed in its nature as an ossified heart must be, could have retained a power adequate to the propelling so great a weight as they have assigned it; and at the same time overcoming the resistance from friction; but in this way the objection of weight and resistance are entirely taken away.

It is to me surprising, that the heart has been assigned as the whole cause and power of the circulation of the blood in the arteries, when it is a truth which every one may satisfy himself of, that all the arteries perform their diastole at the same instant in healthy people.

I know there are those that assert the contrary; but in all the trials I have ever made on myself, by feeling in the different parts of my body, where the pulse can be perceived, I have ever found the pulsation at the same instant; and I imagine, wherever the contrary has been thought, it has arisen from the difficulty of keeping the mind equally attentive to two objects at one time; and thence it has appeared that one artery beat before the other.

From

From all observation which I could ever make also on a person who had the palpitation of the heart, to the greatest degree I ever knew, where the carotid artery had a most violent pulsation, extremely visible; and whose pulse in the legs and wrists I examined with my fingers, whilst I kept my eyes on the carotid, and in all the repeated trials I could make, there was not the least distance between the pulsations of one part and the other.

This pulsation of the arteries being at the same instant through the whole body, is a demonstration that the heart is not the power which propels the blood, and by that means the cause of dilating the arteries, as is manifest from this:

If the heart was the sole power which distended the arteries, the diastole would begin at that part of the aorta which is nearest the heart; because every projection of the blood would have its first effect in that place, and thus, as the blood was impelled thro' the arterial tube, the diastoles would succeed one another in an undulatory manner, according to the passage of the blood all along the arteries, which would probably be very
visible

visible in dissections of living animals; and yet what has never been observed, tho' this tube is dilatable and elastic.

Indeed, in tubes which are not dilatable, the contrary would take place; because the fluid being confined in vessels with unyielding sides, the whole fluid contents would be push'd forward at one time, just as impressing motion on the end of a stick, the whole moves together.

But as the arteries dilate, and are elastic, and as this dilatation is all in the same instant thro' the whole arterial tube, the velocity and force of the blood imparted to it by the heart cannot be the distending power in the diastole of the artery, but some other; and thus another very prevalent proof of the action of vital fire is added to those already mention'd, as this fire has been found to act momentarily in all the distances in which it has hitherto been tried.

That some other power than the velocity of the blood dilates the capillary arteries to give passage to the globules of blood, seems evident also from this, that in those experiments which Dr. Hales has made, in pouring water into the aorta and other arteries of
dogs,

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dogs, tho' water is so much a more limpid fluid than the blood, and its force and velocity equal to that given to the blood by the heart, yet it never pass'd by the anastomoses of the arteries and veins, but thro' the sides of the arteries; and this seems to prove, that the arteries are totally stopp'd by the contraction of their fibres, after the vital fire no longer continues to act; and that the force of the heart has not a power equal to what is requir'd to dilate them.

By this way which we have endeavour'd to explain the motion and power of the heart, it is eas'd of that great force which has been assign'd to it by the calculators of its powers; the cause of that great velocity with which the blood moves is now distributed to the whole arterial tube; and the heart, instead of moving a weight equal to more than that of the blood, by the lowest calculation of former physiologists, in this way of explaining its motion and power, impels no more than two ounces, in supposing the ventricles to contain that quantity in each diastole; and this seems more reconcileable to the divine intelligence which has created this frame of ours, where
the

the powers being equally spread thro' the whole arterial tube, the labour and action of one part is not so greatly superior to the other parts concern'd in involuntary motion.

And in truth, a much greater power than what has been placed in the heart; would not be sufficient to move the blood thro' tubes, the sum of whose areas are continually increasing beyond that of the aorta, where the friction would be so great, if the tube was not dilated by some other power than that of the heart; and where the loss of movement is so great by the branches of the tube going off, and inosculating with the veins at right and oblique angles.

This then we hope, will serve to prove the truth of what has been said on the cause of voluntary motion, and of involuntary in the heart and arteries. Let us see if the experiments made by Dr. Houston at Leyden, concerning the effect of perforating the thorax, and its consequences on respiration, will not confirm what has been said on that head already.

C H A P. X.

An Enquiry into the Cause of those Phænomena which attended the experiments made by Dr. Houston, De perforatione thoracis, ejusque in respiratione effectibus. Quoted by Dr. Hoadley; and how far they are explicable by the manner in which respiration has been accounted for in this Essay.

EXP. V. Jan. 25, 1729.

CAni mediocri, asseri alligato, thorax apertus utrinque, largo vulnere, animali vox non defecit, et pulmones adeo non collapsi sunt, ut per apertus eruperit utrinque illorum lobulus. Lobuli hi extus hærentes dilatari, et contrahi non desierunt, et quod maxime mirum, dilatatio illorum thoracis contractioni erat synchrona et contra, aer in pectoris cava inflatus animalis respirationi nihil nocuit.

Postquam sic per horam vixisset, sine ulla vocis vel respirationis læsione sensibili; thorax ab uno latere apertus fuit ulterius, discissâ costâ. Tumque, apparebat (magnum paradoxum) pulmonem contrahi, dum pectus dilatabatur dilatari dum hoc angustabatur.

Huic etiam operationi supervixit canis donec re ab omnibus abunde perspecta laqueo strangulari damnatus est.

In this experiment, the most remarkable phænomena which happen'd different from those which attended the experiments of Dr. Hales, and Dr. Hoadley, were the lungs dilating in the time when the thorax contracted, the thorax dilating when the lungs contracted, and the lobes of the lungs continuing out at the wounds which were made between the ribs.

These are the phænomena which we would account for; and as it seems to us, that Dr. Hoadley's manner can hardly satisfy even upon his own principles, the mind of any one the least inquisitive and attentive; yet as it has been hitherto unexamined by any writer as far as I know, let us fairly see whether these appearances can be accounted for, allowing all the doctor has said concerning air between the lungs and pleura to be true.

The first part which is endeavour'd to be accounted for, is the lobes continuing out at the wounds made between the ribs, and their dilating and contracting contrary to the dilatation and contraction of the ribs.

“ This appearance, says Dr. Hoadley, we are
“ now to explain. In order to do this it must
“ be consider’d, that those parts of the lungs
“ which are within the breast, are expos’d to
“ the pressure of the air within the cavity;
“ and those parts which hang out at the
“ wounds, are expos’d to the pressure of the
“ external air; and lastly, that all communi-
“ cation is stopp’d between the air within,
“ and that without, by the parts of the lobes
“ thus forcibly thrust out at the wounds at
“ their first being made.”

First then, when the wounds were made between the ribs, the air, if there was any between the lungs and pleura, must have been rarified by the heat of the thorax, and as all rarified air is under a necessity of doing, it must have past out at the apertures made in the chest before the lungs came thro’, and thus the lobes following it, and sticking in the wounds, must have hinder’d the return of cold air. As it is probable also, that the lungs from their being forc’d out at the wounds, filled the thorax in every other part; thus it seems natural to imagine, that if there had been any air in the thorax before the incisions, yet after these were made there could be none, and of consequence the
phæ-

phænomena so apparently contradictory to the common course of nature, cannot be ascrib'd to the air in the thorax.

But let us imagine there was air in the thorax after the lobes continued thro' the wounds, and then see if it would have satisfactorily effected all that has been assign'd to it by Dr. Hoadley.

“ When the breast is contracted, says the
“ doctor, the air in the cavity being condensed, presses more forcibly on the lungs within, than the external air on the ends of the
“ lobes without; in expiration therefore, which is the consequence of this superior
“ pressure of the air in the cavity, part of the
“ air in the lungs, which otherwise would
“ have passed out at the wind-pipe; will now
“ be forced into the ends of the lobes which
“ hang out at the wounds, by which those ends
“ must be dilated when the breast contracts.”

In answer to this we say, it seems impossible that the air between the lungs and pleura can be condensed during the time of expiration more than inspiration, even allowing all Dr. Hoadley's account of the action of the intercostals and diaphragm, to be the true one.

In order to produce any degree of condensation of air by force, (without considering the effects of heat and cold in all the different degrees) which is the doctor's manner, it is absolutely necessary, that the sides of the vessel which contains it, do not continually yield to the impressing power which forces the air into it; and in all condensations of air, the condensing will be in some certain proportion to the weight or force which acts upon it.

Now in the time of expiration, allowing the weight of the atmosphere acting on the breast, and where you will, and adding all the force you please to those intercostal muscles which the doctor destines to the use of expiration, it will avail nothing, unless you can prove that the resistance which the lungs give to the air in the thorax thus compress'd, be something considerable also; for if the lungs very easily yield to the pressure of the air in the thorax, then there can be no condensation of this air in the cavity, and that they do, I desire no other proof than the doctor's own words, where talking of the effects of the pressure of the air on the lungs, as has been differently ascertain'd
by

by other physiologists, he tells us : “ Who-
“ ever will examine the different methods
“ in which these gentlemen form their cal-
“ culations, will readily give the preference
“ to the last : he will never find him at-
“ tempting to build, till he has got a sure
“ and solid foundation prepar’d for him by
“ nature ; and accordingly, the result of his
“ calculation is agreeable to the ease with
“ which nature carries on all her most con-
“ stant works.

“ The impetus (says this author) which
“ the internal surface of the lungs sustains
“ in common respiration, is less than the
“ motion of the gentlest dew descending
“ from the sky, being equal to the motion
“ of a column of water, (whose base is the
“ internal surface of the lungs, and whose
“ height is but the $\frac{1}{70000}$ part of an inch)
“ moving with a velocity no greater than
“ what would carry it thro’ an inch in a
“ second of time.

“ That this is the truth, no one will
“ doubt, if he reflects upon the ease with
“ which respiration is commonly perform’d.”

Thus far Dr. Hoadley, and certain it is, that
the pressure from the weight of the atmos-

phere, is as it is here stated ; and consequently this pressure being almost reduced to nothing, the resistance which it opposes to the air in the cavity at the time of expiration, must be reduc'd to the same influence also ; and thus there can be no possible condensation of the air in the cavity, allowing all the force of muscles and weight of atmosphere on the thorax you please ; because the lungs which is one side of the vessel which contains the air, yields to the least pressure.

Indeed we would venture to say, that even supposing the weight with which the atmosphere distends the lungs in the time of inspiration was equal to fourteen thousand pounds, as some have calculated it, yet in the expiration, it would afford almost no resistance to the compress'd air in the cavity ; because being lighter than the air in the atmosphere, it would tend upwards, according to the known laws of fluids and gravitation, and thus offer no resistance to the pressure of the air between the lungs and pleura.

This seems sufficient to prove, that the air cannot be condensed by the contraction
of

of the breast ; but let us even grant that it may, would it then produce those phænomena so apparently contradictory to nature ?

“ When the breast is contracted, says Dr. Hoadley, the air in the cavity being condensed, presses more forcibly on the lungs within, than the external air on the ends of the lobes without ;” whence comes it then, that this air so condensed in the cavity, does not escape between the lobes and sides of the wounds ? does he imagine that they are so compress’d by the lips of the wounds, that condensed air could not force its way between them ? or how comes it to pass, that the condensed air within on the lungs, and the atmosphere without, pressing at one time upon them, do not force the lobes back into their places, one or other of which would probably happen if there was any air included between the lungs and pleura ?

But to show at once, that this phænomenon of dilating and contracting, contrary to the usual way, did not happen from the air being held in the cavity, by the lobes thrown out at the wounds, and thence operating in that particular manner ; the same thing happen’d when the thorax was far-

ther open'd, discissâ cosâ, tumque apparebat (magnum paradoxum) pulmonem contrahendum pectus dilatabatur, dilatari dum hoc angustabatur; and thus, whatever advantage was gotten in the circumstances of included air and lobes stuck in the wound, to explain these contrary motions at that time, yet it is impossible to avail one's self of them in this latter case, where the lobes were neither stuck in the wound, or a possibility of air being shut up in the cavity after this large wound was made in it; and for this reason Dr. Hoadley is obliged to have recourse to some other manner of accounting for it; we shall see whether it will satisfy us better than the former, after we have transcrib'd Exp. VI. of Dr. Houston, and then try, if proceeding on the principles which were laid down as the cause of respiration, in the chapter on that head, there is not one solution for both these difficulties to be drawn naturally and necessary from them.

EXP. VI.

Canem parvulum, extensis artubus, firmiter super asserem ligavimus, cutis elevatæ portionem forfice abscidimus, ea thoracis parte, qua costæ ab incumbéntibus musculis
minime

minime teguntur, absterfo sanguine et fluxu ejus vini spiritu cohibito, quicquid adhuc costas, et intercostales musculos tegebat, id arreptum tenaculo abscidimus ; tandemque et ipsos intercostales musculos, cautè sepe-
vimus, membrana pleura dicta hoc modo nudata hæcce aspicientibus exhibuit phæ-
nomena.

Dum pectus dilatabatur, apparebat intus membranæ applicatum aliquod album ; dum vero angustabatur pectus et expirabat animal, album illud sursum fugiens locum cessit as-
cendenti cuidam corpori rubro ; tamque mox dilatante se pectore, rubrum iterum descen-
dit, locum ejus occupante albo et sic per
vices.

Hoc viso superius costarum interstitium etiam musculis nudavimus, sed eo in loco apparuit nihil nisi album.

Membrana utraque parte, qua nudata erat dum pectus dilatabatur, fiebat concava, dum angustabatur paululum (sed vix sensibilibiter) convexa.

Hicce ad satietatem contemplatis, discissis duabus costis pectus aperuimus, tam amplo vulnere, ut quicquid fere in eo latere conti-
nebatur oculis pateret.

Animal

Animal hoc pacto, vocem non amplius edidit quamvis ab altero latere thorax ejus esset illæsus. Pulmo multum illico collapsus est ; sed alternum dilatationis et contractionis motum non penitus amisit : eratque omnium aspicientium consensu dilatatio ejus contractioni thoracis synchrona et contra.

The first thing which appear'd after the pleura was laid bare, which is called aliquod album membranæ applicatum, were the lungs undoubtedly, as Dr. Hoadley observes; and here, by the by, it is manifest that there was no air between the lobes and the pleura; for if there had been any, the word applicatum had been very ill used, and without the lungs had touch'd the pleura, they could not have been seen at all; and if there had been any air between that membrane and the lobes, the lungs could not have touch'd it; thus in this instance, as in every other quoted by Dr. Hoadley, there was no air included in the cavity; and yet he still persists, contrary to the experiment, to explain all the phænomena of respiration from that very cause.

The corpus rubrum was undoubtedly the diaphragm, which took the place of the inferior

ferior part of the lobes in the time of expiration, and for this reason ; because the pleura being laid bare farther up, there appear'd nothing but the white substance, both in inspiration and expiration ; and this shows that there was no air between the lobes and pleura ; because the lungs were constantly applied to that membrane in the upper part, and as soon as they disappear'd in the latter, the diaphragm succeeded, which could not have been the case, had there been any air included in the cavity.

The concavity of the pleura in inspiration, arose from the lungs pressing up between the ribs, and convex, tho' scarce any thing, because, in expiration, the ribs come nearer to each other.

Thus then, in this instance, Dr. Hoadley can draw no resource from included air, because there was none ; and if there had been any, *discissis duabus costis*, it must have escap'd.

To explain therefore, the reason of this contradictory motion in the lungs, to the dilatation of the breast, et vice versa, he imagines that the lobe on the side which had not been open'd, had a contradictory motion to the lobe on the side which had

been open'd, and that the sound lobe in the act of expiration, the air being condensed in it, instead of letting it pass off freely thro' the trachæa, according to the tendency of all heated air, was forced into the left lobe, and thence arose the contrariety of their motions.

We have already shewn, that it was impossible the air in the cavity can be condensed; because one side must yield to the impressing power; and here it is yet more manifest, that the air in the lungs cannot be condensed; because, suppose all the power you will in the lungs, thorax, diaphragm, and all other parts concern'd in respiration, yet there remains an opening on one side, that is by the aspera arteria, and thus the least force applied to condense the air in the lungs, would force it thro' the wind-pipe; and hence it is impossible, condensation can take place in the air of the lungs. Thus then, this article of condensed air being impossible to be admitted, it cannot be the cause of the irregular and unnatural phenomena which appear'd in the lungs and thorax of this dog.

It is remarkable also, that to account for this contradictory dilatation of the lobes and thorax on the wounded side, Dr. Hoadley concludes that the lobe on the entire side, moved contrary to this in the left; and was in its dilatation when the other was contracted, and yet Dr. Houston does not mention this, nor could he, because he could not observe the lobe which was inclosed; however, we hope to prove that both lobes, dilated and contracted at the same time; and the different and contradictory appearances, arose from the wounds in the open'd side.

In order to explain these phænomena more satisfactorily, it must be remembered, that in the account which we have given of respiration, the intercostals are assigned to act only in the time of expiration, and the rarifying air is the principal cause of the dilatation of the breast, after the lungs have had the expanding motion communicated to them by the vital heat operating on the vesicles of the tunica cellularis.

This being the case, a wound being made between the ribs, where it was made in this experiment, the lobes finding no resistance to that force which is imparted to them by
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the rarifying air (which force whoever will recollect what fire or heat effects upon air, will easily conceive equal to this production at least) fly out through the wounds ; and there continue as long as the air which enters by the aspera arteria can be rarified by the heat in the thorax ; and this also proves that there is always some force necessary to compress the lungs, and the dilatation of them by rarifying air is the natural one ; this then may satisfy us in this phænomenon. Let us now explain that other of the dilatation and contraction of the lungs, being contrary to these motions of the thorax.

To do this, we must remember that the intercostals are considered as two muscles, whose fibres intersect each other ; and fastened at each end at two immoveable points, or something equal in its effect to it, and that by the contraction of their whole lengths, as the two points to which they are fixed, cannot be brought nearer to each other, the depression of the ribs is the effect of their action.

This being the true state as it is in nature, let it be seen what effect a division of those muscles between the ribs will cause

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on two ribs amputated. This division being made, the fixed points to which the intercostals are attached, remaining the same; these muscles must no longer be considered as two, but as four muscles, as the continuation is destroyed by the incision; the upper part of the muscle being fixed to the rib next above the aperture, and the lower to the rib beneath it.

Whenever these muscles act, they must draw the ribs asunder at the incision, the upper part of the intercostals shortening by action, must draw the ribs up, towards the point to which they are fixed; and the under part acting in the same manner, draw the ribs downward to the point to which they are attached below; and thus the very same action which depressed the thorax and rendered it less, whilst the continuation of their fibres ran from one fixed point to another, encreased its capacity, and elevating one part of the ribs, which was above the incision, and pulling down that part which was below it, after the muscles were divided; and in consequence of this, when the muscles were relaxed from the intermission of the action of the vital heat, then the breast apparently subsided;

subfided ; and thus is must necessarily follow, that the motion of this fide of the thorax, was inverted, or contrary to the natural courfe.

By this means the dilatation of the thorax being quite oppofite to its ufual time, and the lungs continuing to dilate in the natural way, the expansion of the lobe of the lungs on this fide became fynchronous with the contraction of the breast, and the dilatation of the breast, at the fame time with the depression of the lungs ; and all this difference arofe from the fame powers operating as they did in the natural ftate, though the effect was different, by means of the incifion between the ribs ; and give me leave to obferve this alfo, that the ribs being not divided in this manner, in the experiments of Dr. Hales and Dr. Hoadley, this contradictory dilatation and contraction of the lungs and thorax could not take place, becaufe a fmall wound in this part will not fufficiently divide the intercoftals, to produce this effect ; the fibres beyond the wound at each end having their continuation ftill intire from one fixed point to the other, the fame alteration which is made by a large wound, will not

be effectuated here; and thence it follows, that these phænomena of the dilating and contracting lungs, being contrary to those motions in the thorax, cannot happen; and this appearance will ever be found by the experimenter to be true or false, according to the size of the wound which is made between the ribs, as several experiments made in this manner have convinced me.

Thus, without inverting the order of nature in her operations, or searching imaginary principles to explain this phænomenon, this way of accounting for it will satisfy every person who will be at the pains to examine into the manner in which we have shewn respiration to be performed; and these experiments are also a demonstration of the truth of that account which we have given on that head.

It has seemed all along, through the account given by Dr. Hoadley, something strange, that he should have considered the air condensed and rarified, as cold air is in the condensing engine; and at the same time, that he should have paid no attention to the effects which air rarified by heat has upon all bodies in which it is included; and this the more, because he allows that the weight on

the lungs is almost nothing; and yet he must agree, that the heat in those parts must be very considerable.

It is no wonder that after so large a wound was made in the thorax, by the cutting off two ribs, that the dog lost his voice, because the cold air being so intimately communicated to the surface of the lobe on that side, and to the mediastinum, the lungs were not enough distended to contain air sufficient to be articulated into sound, the heat, which was the power which must rarify the air that is let in through the wind-pipe, being destroyed by the admission of cold air into the cavity of the thorax; and thus the voice failed in the animal, of necessity.

That this was the reason of it, the very words of Dr. Houston tell us, where, after the wound was increased, he says, *Pulmo multum illico collapsus est, sed alternum dilationis & contractionis motum non penitus amisit*; which is the same as to say, that the motion of the lungs was still barely perceptible; and thence it was no wonder that the voice should fail when there was no air contained in the lobes of the lungs.

We will beg leave to quote one experiment made by Dr. Hales, in his *Analyfis* of the air, which seems to offer the strongest proof in favour of what has been said on respiration, and then omit all others, though almost every experiment which has been made by philosophers would confirm the truth of our manner of accounting for it.

EXP. CXIV. Hale's Vegetable Statics.

“ I tied a middle-sized dog down alive on
“ a table, and having laid bare the wind-
“ pipe, I cut it asunder just below the la-
“ rynx, and fixed fast to it the small end of
“ a common foffet ; the other end of the
“ foffet had a large bladder tied to it, which
“ contained 162 cubic inches ; and to the
“ other end of the bladder was tied the
“ great end of another foffet, whose orifice
“ was covered with a valve, which opened
“ inward so as to admit any air that was
“ blown into the bladder ; but none could
“ return that way ; yet, for farther security,
“ that passage was also stopped with a
“ spiggot.

“ As soon as the foffet was tied fast to the
“ wind-pipe, the bladder was blown full of

“ air through the other foffet ; when the
“ dog had breathed the air in the bladder to
“ and fro for a minute or two ; he then
“ breathed very fast, and shewed great uneasiness, as being almost suffocated.

“ Then with my hand I pressed the bladder hard, so as to drive the air into his lungs with some force ; and thereby make his abdomen rise by the pressure of the diaphragm, as in natural breathings ; then taking alternately my hand off the bladder, the lungs with the abdomen subsided, I continued in this manner to make the dog breathe for an hour ; during which time, I was obliged to blow fresh air into the bladder every five minutes, three parts in four of that air being either absorbed by the vapours of the lungs, or escaping through the ligatures upon my pressing hard on the bladder.

“ During this hour, the dog was frequently near expiring, whenever I press'd the air but weakly into his lungs, as I found by his pulse, which was very plain to be felt in the crural artery near the groin, which place an assistant held his finger on most part of the time ; but the languid

“ languid pulse was quickly accelerated, so
“ as to beat fast soon after dilated the
“ lungs much, by pressing hard on the
“ bladder, especially when the motion of the
“ lungs was promoted by pressing alternate-
“ ly the abdomen and the bladder; where-
“ by both the contraction and dilatation of
“ the lungs was increased.

“ And I could, by this means, rouse the lan-
“ guid pulse whenever I pleased, not only at
“ the end of every five minutes, when more
“ air was blown into the bladder from a
“ man’s lungs, but also towards the end of
“ five minutes, when the air was fullest of
“ fumes.”

If we fairly examine the phænomena in this experiment, we shall clearly see that the inflating power is chiefly lodged in the air’s being rarified by the heat of the thorax and viscera contained in it, after the expanding direction has been given to the lobes, by the vital fire acting on the fluid in the vesicles of the tunica cellularis of the lungs; and that the intercostal muscles and diaphragm, have no natural action of their own during inspiration, but are totally passive, and destined for the office of expiration, which they perform alone.

First, the dog was almost suffocated, after having breathed the air to and fro for a minute or two : this symptom arose from the air in the bladder being almost equally heated by the breathing, with that in the lungs ; and, according to this degree of heat, there was very little liberty for the air in the lungs to pass out, and fresh air to be admitted in the place of it, because of this equability of heat in each place ; and thus also the air that was drawn into the lungs from the bladder, at every short breathing being almost as hot as the thorax could make it, before its admission, the expansive power was lost upon it, and all rarification and distension of the lungs almost at an end, because every degree of heat has a limited power of expanding the air : and here in this case no greater degree could be added ; whence it follows, that the air not being capable of any farther rarification, after it was heated and admitted into the lungs, the lobes could be no more dilated, and suffocation was almost at hand.

But notwithstanding all farther power of dilating the lungs by rarifying air was at an end, whenever the air was press'd from the bladder into the lungs, which pressure was
analo-

analogous to the rarification of cold air, the breast was elevated, and the diaphragm pushed down; the pulse also, which was before languid, was quickly accelerated, and the dog revived.

Thus then you see, that by this additional force of the hand pressing on the bladder, the intercostals and diaphragm were put into motion by the air which entered the lungs; and as soon as the pressure was taken off, it was again expelled, and they returned to their former situation, that is, the breast was depressed and the diaphragm returned into the thorax; and thus the muscles continued till they were moved again by a fresh pressure: now, in this experiment, there is a manifest exhibition of the action of the lungs and muscles in inspiration and expiration.

After this, when we consider how near the dog was expiring, before the pressure of air from the bladder into his lungs, and how much he was eased by it; how undeviating also it is in all nature, when in pain, to endeavour after its ease, we can scarce withhold our assent, but that if the intercostals and diaphragm had been concerned in elevating the breast to cause inspiration, and

under the direction of volition, the dog would have dilated his breast to have been freed from the pain he was under ; but this not being once done, through the experiment, is little less than a demonstration that it was not in his power, and that these muscles are designed only for the use which we have assigned them, that of expiration. .

It is remarkable also, that the pulse mended on the lungs being expanded ; which seems to confirm what was said of the blood's passing freest when the vessels are least contorted, and vice versa ; and hence the necessity of breathing, after it has once began, to continue life.

From what has been said on the experiments of Dr. Houston and Dr. Hales, it seems evident that Dr. Houston was right in his conclusion, that there was no air between the lungs and pleura ; and indeed, Dr. Hoadley, in speaking of the adhesion of the lungs to the pleura, has said, " This is so common a case, that I believe the number of those who upon dissection are found with adhesions, greatly surpasses the number of those without them." And again, he allows the possibility of an universal adhesion of the
exter-

external surfaces of the lungs on both sides the mediastinum, to the parts which are immediately next them, which amounts nearly to the same thing as to allow that respiration may be carried on, and life supported, tho' there be no air in the cavity of the thorax; and seems giving up the necessity there is for the existence of air in that place, and the uses of it which have been so much insisted on in his lectures.

If this be true, then I think the necessity of air between the lungs and pleura, must be given up, because Dr. Hoadley himself tells us, in the preceding paragraph, that an universal adhesion of the lungs to the pleura is more than possible, when he says, "In
" lungs which have been diseased for a long
" time the adhesion gradually spreads, and
" sometimes becomes universal. This is a
" case I have myself seen more than once, and
" requires our attention." And yet, tho' this adhesion had been seen by him, which ought, according to the preceding paragraph in his book, to have destroyed all probability of air being between the lungs and pleura, yet he says, notwithstanding this, "I make no doubt
" but

“ but the experiments of Dr. Hales mention-
“ ed in the first of these lectures together,
“ with the last of Dr. Houston, must convince
“ any impartial reader, that there always is a
“ quantity of air contained in the cavity of
“ the breast of every one who breathes freely
“ and easy.” Which seems just the same
thing as to say, that though I myself have
seen a phænomenon in nature, which abso-
lutely destroys the possibility of air being be-
tween the lungs and pleura, yet my reason-
ing upon the experiments of Dr. Houston
and Dr. Hales must convince every impartial
reader, that what I saw had not the power
of destroying the probability of air being
between the lungs and pleura.

Indeed, after he has said, that the num-
ber of those who have adhesions greatly sur-
passes those who have none; that there are
adhesions on both sides the breast, which, for
the same reason, give little or no trouble in
respiration; then considering, that if there
was any air between the lungs and pleura,
these adhesions could never probably take
place; or if they did, that the air between
the lungs and pleura in expiration must, ac-
cording

according to Dr. Hoadley's way, endeavour to separate the lungs from the pleura, and give pain in that part; it is surprising he persists in his manner of thinking.

But as these pains are never felt in expiration, at least it is highly probable, that there is no air in those cases where adhesions have taken place; let us see how the conclusion would turn out in reasoning, according to this superior number of adhesions. Would it not be thus, that as the number of adhesions of the lungs to the pleura, is greater than the cases where there are none, so much the probability of no air being included between the lungs and pleura, is greater than that there is any.

Again, as in the cases of adhesion, if it should be thought impossible, that there can be any air between the lungs and pleura; and as in those other cases where there is no adhesion, there is no necessity of air to prevent it, because the perspiration and smoothness of the pleura will effectually hinder that, we ought to conclude that there is no air between the lungs and pleura, both instances being reconcileable to the lungs and pleura being always in contact, or no air
being

being between them ; and only that where there is no adhesion with the being of air in the cavity of the thorax. Thus then we should conclude, from the uniformity in the actions of nature, and from the superior number of adhesions, that there is no air in the cavity of the breast, rather than from an inferior number of instances that there is.

Thus then we hope to have laid down what is sufficient to satisfy physiologists of the truth of that which is assigned by us, as the cause of vital motion ; and of the manner in which it is performed. Let us now examine the different effects of different degrees of heat on animal substances ; and first endeavour to show what it is which sustains and continues the vital heat after the birth of the fœtus.

C H A P. XI.

*The Crassamentum, or red Globules in the Blood
the Cause of the continuation of the Calidum
innatum, or vital Heat after the Birth.*

AFTER having endeavoured to explain the cause of vital heat and vital motion, let us see in what manner it is continued after the birth of the fœtus, and whether the crassamentum or red globules are the true cause of this continuation.

That the blood has been considered as the true source of vital fire, amongst the ancients, Plato and Aristotle will inform us ; as does also our celebrated Harvey, whose soul was warmed with the finest fire of imagination, and without which superior faculty, nothing new or great can ever be expected from human nature. Sir Isaac Newton himself having possessed it in a very eminent degree, as is evident from his Optics and Queries ; and indeed the investigating truth, thro' different problems in the mathematicks, by which any thing new is to be discovered, requires a fertile imagination.

The sterile and mis-named reasoning head, may, by persisting with infinite labour and unwearied diligence, direct the possessor of it to tread in the steps which former mathematicians have left behind them, and understand what has been already written on that subject, as Tully has told us long since, speaking of the mathematics, *Quo tamen in genere ita multi perfecti homines exstiterunt, ut nemo fere studiosus ei scientiæ vehementius videatur, quin, quod voluerit, secutus sit;* by which he must mean only the knowing what was already written ; but he will never conceive one new idea, or discover one new path ; he may walk to the very boundary of other men's inventions ; but at that point he will be held as by a magic circle, and never place one footstep beyond it.

It is not in poetry, painting, music, architecture, and those works which are generally called of fancy alone, that a superior degree of imagination is required to produce any thing truly great and natural ; the most abstruse metaphysical and mathematical researches equally demand it : without it how will you combine or separate, compare or distinguish, settle or change the order of

the parts which enter into the subject you are examining, to discover its truth or falsehood? And the event or success of human enquiries will ever be proportion'd to the nature, extent, and rectitude, of that superior power, imagination, or genius, and the application which is made of it.

To me it appears evident, from what this great man has said in his works, *De generatione animalium*, that had the same discoveries of the nature of fire been then made which have since been brought to our knowledge, by experiments on the electrical machine; and the parts which compose an animal, so well understood and described as at present, that the difficulties which have hitherto attended the accounting for vital heat and motion, would have received a thorough solution from his hand.

However, tho' he did not see in what manner the blood was the cause of these phænomena, yet he saw intuitively, as is the manner of superior souls, that it was the cause of the continuation of vital heat and vital motion. He despised the fallacious and futile resource of animal spirits; and says, *Solemus rerum negligentes, speciosa nomina*
vene-

venerari. Sanguis, qui nobis præ manibus atque oculis est nil grande sonat; ad spirituum vero, et calidi innati, magna nomina obstupescimus, detracta autem larva, evanescit ut error, sic admiratio. Some of the ancient stoics have believed and asserted, that the soul itself was fire, tho' of a different nature from the common.

The idea which Harvey entertain'd of the callidum innatum, or vital fire, and of vital motion, as residing in and being sustain'd by the blood, will be best seen from his own words, in his 51st Exercitat. Ita neque Aristoteli ipsi assentiri possum, qui cor esse particulam hanc primum genitalem et animatam statuit, nam revera sanguini soli privilegium hoc deberi existimo: is enim est, qui primus in generatione conspicitur idque non solum in ovo, sed in omni foetu, animaliumque conceptu primo contingere, mox palam fiet.

Apparet, inquam, ab initio, punctum rubrum saliens, vesicula pulsans, fibræque inde deductæ sanguinem in se complectentes, et quantum ex accurata inspectione discernere licuit, fit sanguis antequam punctum saliens efformatur, idemque calore vitali præditus est,

est, priusquam per pulsum cietur: atque ut in illo et ab illo pulsatio incipit ita tandem, in ultimo mortis articulo, in eodem definit, quippe plurimis experimentis, tum in ovo tum alibi factis compertum habeo; sanguinem id esse in quo [quamdiu calor vitalis non prorsus evanuit] potentia redeundi in vitam continuatur, et quoniam vesicula pulsans, indeque productæ fibræ sanguineæ, ante alia conspiciuntur; crediderim rationi consentaneum, ut sanguis suis receptaculis prior sit; contentum nempe suo continente; siquidem hoc factum est, ut ejus usui inserviat, ideoque fibras, et venas, posteaque vesiculam, et demum cor, utpote organa recipiendo, ac retinendo sanguini destinata hujus solis transmittendi, et distribuendi gratia extracta esse, verisimile est, sanguinem esse particulam corporis principalem.

Idque ex multis observationibus liquet; præsertim, cum quædam animalia eaque sanguinea diu absque pulsu vivant; et nonnulla totam hyemem lateant, et tamen in vivis supersint. Licet interea eorum corda ab omni motu cessent, et pulmones a respiratione feriantur eorum instar, qui in syncope, lypothymia, aut effectibus hystericis semi mortui jacent cum asphyxia.

Factus itaque certior ex iis, quæ in ovo, et vita animalium dissectione observavi; statuo [contra Aristotelem] sanguinem esse primam particulam genitalem et cor esse ipsius organum, circulationi ejus destinatum, quippe functio cordis, est sanguinis propulsio, ut in animalibus omnibus sanguineis luculenter patet: idemque [in generatione pulli] est officium pulsantis vesiculæ, quam in primis animalium conceptis [non minus, quam in ovo] sæpe numero videndam exhibui scintilla minorem, micantem, et in actione sua sese constringentem sanguinemque in contentum una exprimentem eundemque relaxatione sua recipientem denuo. And afterwards he says, Nec sanguis solum pars primigenia et principalis dicendus est, quod in eo et ab eo motus, pulsusque principium oriatur, sed etiam quia in eo primum calor animalis innascitur spiritus vitalis ingeneratur et anima ipsa consistit. And again, Vita igitur in sanguine consistit.

From these passages, and innumerable others in his writings, it is evident, that this great man not only ascribed vital heat and vital motion to the blood, but even the very existence of the soul itself. Whether that be strictly true or not, I shall not take upon
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me to decide in this place; but this far I will undertake to say, that the union of the soul with the body, and the increase or decrease of the powers of its faculties, depend greatly upon the state of this vital fluid.

Does it not hence almost appear intuitively evident from the words of Harvey, that the account which has been given before in these sheets, in which the cause of vital heat and vital motion are ascertain'd, must have been discover'd by this great physiologist, if the experiments now so well known had then been discover'd.

In advancing then, that the crassamentum of the blood is the cause of the continuation of vital heat in the animal body, we have said nothing new as far as that goes; the whole progress that we have made in this essay, is the shewing how vital motion is produced by the effects and operation of the vital heat, and the cause of the continuation of vital fire, by the attraction of the red globules of the blood, which we are about farther to explain; the whole that is attempted in these papers, being to assign a more probable philosophy to solve the difficulties attending it, which have hi-

therto remain'd inexplicable, and to ascertain the cause of those truths which our great Harvey saw, and yet could not explain, thro' want of sufficient discoveries.

In order to establish this philosophy more firmly, on which so much of that happiness, health, so essential to the well-being of human nature depends, let us begin where this vital heat first begins in animal nature; and try if, by tracing it from its first footsteps, we can follow it thro' the maze by which it has escaped all research, and find, at the end of our pursuit, the secrets which have lain hid from the enquiries of all physiologists who have hitherto written on the subject.

To effectuate this let us begin with the very first application of fire to the impregnated egg: this then being applied to an egg to the degree of 32, by Reaumur's thermometer, in twenty one days produces an animal perfect in all its parts, as the parent from whence it sprang; the first appearance which takes place in this egg, after incubation, of dawning life in the new being, is the red globule, and then the punctum saliens: let us now pursue these phenomena,
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and observe by what means these red globules or crassamentum, and the vital heat, are continued throughout its existence; and after that, let us enquire what powers or causes are continually counteracting the effects of this vital fluid, by which the animal heat and animal motion are diminish'd and dissipated, or, in fact, in what consists health and life, disease and death.

The first alteration which appears in an egg, after incubation, or being placed in a proper heat, worthy our attention, is the red drop received into and expell'd, by the punctum saliens: this phænomenon appears in less than eight and forty hours after incubation; and to the effecting this change in the cicatrix and fluids of the egg, there is nothing necessary but the application of a degree of heat equal to that of a healthy animal, no vital principle, or emanation of the soul, to be imparted from the parent to this beginning foetus, nothing otherwise than that which the common fire or heat can give, whether from the heating horse-dung, the oven, or the parent; let but the degree be equal to that of the 32d degree, by Reaumur, it is as effectual in producing an animal

from an egg, similar to the parent, and equally perfect, as if thro' the whole time of incubation it had been warm'd by the genial heat of the womb or bosom of the hen.

Thus then, the change of the humours in the egg from white to red, and the beginning motion, is due to this degree of fire or heat alone; and by the continuation of this degree of heat equal to .32, by Mr. Reaumur's thermometer, for one and twenty days, the humours of the egg are converted into blood, and an animal perfectly form'd, and brought to life and light.

It will be of no consequence, in this place, to enter into any disquisition concerning the manner in which the egg is impregnated by the male, or what it is which gives fecundity to it; let it be in what manner you please, no egg however impregnated, without the application of this degree of fire, ever becomes an animal, and to the continuation of this fire, the duration and support of life is ever after owing; nor is it at all necessary, that it be explain'd in what manner this fire operating on the fluids of an egg, changes its substance from white to red; we see it
does

does it, and without it, that this effect cannot be produced, in going back too far in our researches, by asking the cause of fire, and the power by which it changes the nature of fluids from one colour to another, from the white of an egg to the crassamentum of the blood, from an insipid inodorous water running thro' the tubes of a vegetable, into fragrant blossoms, and fruits of the finest flavour; we go wrong, we should, after having seen the effects of fire, in different degrees, on different subjects, reason analogously from them, and after the existence of that element has been discover'd, and found absolutely necessary for the continuation of life and motion in an animal, then by examining the fabric and organization of an animal being, and applying the known powers and properties of this element to that being so form'd, we should endeavour to explain by what means and influence life and vital heat are continued and held within the body and motion supported. Of what use would it be to discover the cause of attraction, since the laws of it, and utility arising to mankind in the application of them, would be the same without that discovery; going

backward to trace out its cause is deviating, and going forward in search of its effects is the true path of the philosopher; and if this method had been always hitherto pursued, as it was by that superior genius Sir Isaac, so much time had not been lost in frivolous research, but much advantage had been drawn from useful enquiry.

Thus then, to heat alone to the degree of 32 by Reaumur's thermometer, is owing the existence of this animal, and the change of the fluids contain'd in the egg into craffamentum; and to the quantity of this craffamentum in the blood, for ever after is the degree of vital heat owing in all animals whatever.

That this is no new doctrine, is as evident as any thing in ancient philosophy. Hippocrates, Aristotle, and Andreas Cæsalpinus have told us in their writings, that in proportion to the craffamentum in the blood was the degree of heat in all animals; and by experiment I have found, that oxen, sheep, dogs, as well as geese, ducks, hens, pigeons, and other animals, whose degree of heat is superior to the human, have a larger proportion of craffamentum in their blood than mankind in health.

The blood of one of these animals contains in the same quantity of it twenty-five times as much crassamentum or red globules, as that of a crab, and its heat is in proportion, beginning from the heat of the atmosphere, which is common to both animals; and those fishes which are scarce warmer than the element they swim in, have a very small proportion of the red globules in their blood.

Dr. Langrish, by a great number of experiments made on blood drawn from people in ardent fevers, has always found, that the vital heat was increased in proportion to the increase of the crassamentum, and the adhesion or attraction of the crassamentum, in proportion to the heat also.

From other experiments on blood drawn from healthy subjects, he found that the crassamentum was always somewhat more than one half the quantity of blood which was drawn; and it is a known observation, that as the crassamentum diminishes in its quantity, the vital heat lessens also. In chlorotic or leucophlegmatic indispositions, where the quantity of serum is in an over proportion to the crassamentum, the animal heat is

is much below the ſtandard of health ; and the adheſion or attraction in the particles of that part of the blood, much leſs than what it is when the heat is greater. Hence it is plainly manifeſt, that the animal heat and adheſion of the particles of the craſſamentum, are in proportion to the quantity of that part in the blood.

Thus then, this callidum innatum, or vital heat, appears to be no more than fire, or a certain degree of heat, held and attracted by the red globules or craſſamentum, after the fire had been communicated by ſome external means, long enough to generate theſe globules in the fœtus of an animal.

Thus we ſee there is no ſuperior power in the blood of an animal, but this power alone of attracting fire in greater quantities from the earth, than many other ſubſtances ; and when the effect and operation of this fire on the animal frame is conſidered, we ſhall ſcarce wonder at its being the very ſoul itſelf, which informs and actuates its being, nor at its epithet of Anima mundi, when to its influence and activity, things animate and inanimate receive the firſt vital principle, and the latter their changes and gradations.

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This power of attraction has been observed in the red globules of the blood of that fish called a muscle; and quicksilver agitated in a phial has been found attractive, unless it was the glass which was made electric, by friction which contained it. Hale's Hæmast.

After what has been said to prove, that fire is a real and permanent being, equally elementary with water, air, or earth, it is hoped that the belief of its being generated by motion of the minutest particles of matter or friction, is at an end; and that its increased quantity arising suddenly in any fluid or solid, arises only from the attraction, which is increased in that solid or fluid.

That fire is attracted by some particular bodies more than others, is a phænomenon analogous to what is seen every day amongst other parts of matter: sal tartari or sal diureticus, exposed to the open air in the driest day, will attract moisture from the atmosphere, and liquify, when even the sal nitri, and common salt, each soluble in water, will grow drier in the same air. What is there then more extraordinary in the fire being attracted from the bodies around it by a particular substance, than water by another particular substance.

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The phosphorus made from animal bodies, attracts the fire from the air, even to a degree of burning, as does also the dry phosphorus made of meal and alum; what is there in this more singular, than in the attraction of water by salt of tartar. Ol. cario-phil. and sp. nitri. fort. thrown on each other taking instant flame, even in the exhausted receiver of an air-pump, and yet sp. nitri extinguishes fire as perfectly as water, being thrown on a flaming substance, on wood or coals. Sp. vitri. mixt with water rises the thermometer eight or ten degrees, and consequently attracts the quantity of fire sufficient for that purpose, on being mixed; and an infinity of other mixtures attract heat in different degrees.

Ol. vitriol, and common water, by being mixed, attract a great degree of heat, and yet these fluids are each of them uninflammable. Thus it seems that the attraction of heat by these red globules, is not at all contrary to the common proceeding of nature; and it has been already shown, that the vital heat is always in proportion to the quantity of crassamentum; and that the attraction of the

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particles of this part of the fluid is in proportion to the vital heat.

It is certain also, that different fluids, which are not under any regular organization, are actuated upon very differently by the same degree of heat ; and many of these substances are capable of holding more fire than others: the degree of heat which can be communicated by all the fires of *Ætna* and *Vesuvius* to water, will never carry it above the degree 212, or boiling, by Farenheit's thermometer ; and yet oil, by any common fire, will rise the thermometer to 600 ; yet this last fluid is much lighter than water. It is visible also, that water flies off very fast in vapour, with the common heat of the atmosphere ; and yet the particles of oil are evaporated very slowly, with the degree of heat equal to 600.

The same fire creates different degrees of heat in two fluids contained in one vessel, water and oil, or water and quicksilver ; in the first instance, the oil which swims above the water, shall be much hotter than the water below ; and in the second, the quicksilver at the bottom shall be much hotter than the water above, and yet both contained in the same vessel on the same fire. The
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heat of the fun will extend a metalline substance much more than a superior degree of heat in water.

Thus, some substances are more adapted by nature, to conceive a greater degree of heat than others; as others are to retain it after received to a certain degree. Spirit of wine depurated of all its phlegm, holds fire as long as there is a drop of the spirit remaining, as does rosin, sulphur, oils, and many other inflameable substances. If this fire be communicated originally to it by some substance in flame, this attraction then of fire by the craffamentum, is analagous to what is every day observable in common life.

That the human body attracts fire, is shewn by this experiment: If you electrify an iron bar, which is blunt at the end, you will see the fire streaming out at the corners of this end; then, if you apply your finger between these two streams, at a little distance, from the end of the bar, you will see the streams bend round to touch your finger, which is a demonstrative proof of that body's attracting fire, which can thus bend the rays from proceeding in a strait line.

The experiment of Pere Bertier, proves, that fire is always passing off from us, and
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probably in proportion to the quantity attracted from the earth during the time of health.

And Mr. Watson's experiment shews us, that by the powers of attraction in electric bodies alone, that the vital fire cannot be much lessened ; for unless there is a communication between the man that rubs the glass and the earth, when all the other parts of the apparatus are placed on electrics per se, there will be no electric phænomena or appearance of fire, after three or four turns of the wheel ; and the surplus is attracted from the person who had his hands on the glass globe.

That this part of the blood, called the crassamentum, is that which attracts the heat ; what plainer proof can be desired than this, that all animals are hot in proportion to the crassamentum which is found in their blood ?

At the same time, it is not fire alone indiscriminate from the degree of it which constitutes and preserves the vital heat and vital motion, though the degree of 96, according to Farenheit himself, or 97 or 98, according to Dr. Martin, by the thermometer made on the same scale, be the heat of

a healthy human creature ; yet it mounts to 103 in some quadrupeds, and to 107, or beyond, in pigeons and domestic fowls ; and it falls down to little above the degree of the atmosphere at common times, in insects, reptiles, and most fish ; and according to the degrees of heat originally destined to each animal, and the excess or decrease of it, will be the state of its activity and health : even in vegetables the same thing takes place ; the heat which produces an apple to perfection would never bring forth a pine-apple ; and the firs which thrive and look green on the bleak and snowy hills of Norway, would perish with heat in the burning sands of Barca ; whilst the spicy vegetables of the east, which breathe incessant sweets, amidst the glowing soil of Arabia, would languish and expire in that cold clime which breeds the lofty oak.

The heat, which hatches the chicken from an egg, would destroy the whole race of fishes, if it effected their spawn ; and thus the very same element which makes an animal complete in one degree, and in one species, destroys its existence in another species, with the same degree.

Nor is the degree of heat, which is necessary to bring any particular animal to life, capable of much variation; that of 32 by Mr. Reaumur's thermometer, is the most perfect for fowls; 36 was a heat which the foetus could not bear and live, after it had began to exist, from its excess; and 28 would neither produce a chicken, nor sustain it, after it had been produced by that of 32.

The degree of heat which would destroy the motion of the heart of a frog, by tearing all the vesicles of the tunica cellularis into one, and overdistending the muscular fibres of it, would not be sufficient to keep the heart of a sheep in action: thus health depends on the degree of heat which is natural to each animal, and which was first imparted to it by that divine intelligence, which is alone able to actuate and inform.

Thus then every degree of heat above 96 or 98, tends to the destruction of that person who possesses it, as well as all degrees, which sink below that number; and this consideration of the excess or decrease of animal heat, and the fatal effects of it, together with the changes, which the animal body undergoes from it, has been but very

little attended to, and very imperfectly explained. It is principally owing to this encreased or diminished degree of vital heat, that the diseases incident to human nature take their rise, and to the neglect of considering them in that light, that they are so badly treated.

Thus then, in examining and reasoning on the effects of fire, and by proving and considering it as a real and permanent being, attracted by different substances in different degrees, we reduce that philosophy, which has been so vague and various in its manner, of explaining the cause of vital heat and vital motion, to that simplicity and appearance which it has to every sense, that is, to fire actuating the human frame with a degree of heat equal to 96 or 98, by Farenheit's thermometer ; and to this fire alone, that all animal motion, and animal heat are owing, is obvious to the meanest capacity, and the disunion of this element from the body, which the touch will tell us is the fact, is death ; and in all languors as people become colder they grow more feeble and motionless, as on the contrary strength returns with returning heat ; for this reason, whenever any sudden death threatens, either by falling

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into water, or otherwise, whilst the fluids are in a healthy state ; the person to whom this accident happens, should not quickly be given over, for till the crassamentum is fixed in the blood, there is always expectation of returning life, particularly by breathing strongly the breath of another person into the lungs of that who is in danger : by this means, an instant warmth is communicated to the lungs and heart, and many a human creature may be saved by this way of communicating heat, which would otherwise have been lost, rubbing their bodies with spirits of wine, and warm cloths, application of warmed substances to their feet, and all ways of communicating heat that is not excessive.

From what has been said, it appears that vital heat and vital motion; in different animals, are entirely owing to the degree of fire which was originally imparted to them by the author of all things, and that excesses of either side that degree in the scale, are fatal to the existence of the being where they arrive.

In thus considering the fire as an element, and drawn from the earth by the attractive power of the crassamentum, the callidum in-

natum, solar fire, anima mundi, are one and the same vivifying principle, which actuates all the different orders of material being ; and thus facts and philosophy are united ; and the explanation of the cause of life and motion, discovered by reason and experiment, is the same with that which our senses intuitively inform us to be the true : and give me leave to say, that in general, wherever the account given by reasoners, as they are called, to explain the cause of any phenomena in nature, is contradictory to the obvious apprehension of the senses of a plain understanding, there is reason to suspect the truth of it.

We will now endeavour to shew, that there is in nature, and her productions, some certain substances, which have the power of counteracting the effects of fire, or repelling it from bodies, by which its degrees and influence may be much lessened.

C H A P. XII.

Of those Substances in Nature, which have the Power of counteraſting the effects of, or repelling fire.

THAT there is ſuch a power in nature which oppoſes or repels fire, is evident both to our ſenſes, and by experiments made on the thermometer.

How often, in the hotteſt months of ſummer, even here in England, does the change of the wind reduce the heat of the atmofphere many degrees in a very little time: now unleſs there was ſome quality brought in this wind different from what was in the atmofphere before it blew from that point; and which had the power of repelling the particles of fire contained in the air before their arrival, how would it ariſe, that the ſun being at the ſame diſtance from us, the ſky equally ſerene, and all viſible cauſes the ſame as before, that this alteration in the degrees of heat ſhould be ſo remarkable and ſudden?

In ſome parts of the continent of America, the tranſitions from intenſe heat to intenſe

cold, are so sudden, on the change of the wind, to some of those which come over the northern tract of the continent, that the inhabitants, from being parched almost to death with the violent heat, when the lightest garments are almost intolerable, are obliged with precipitation to put on great quantities of clothes, and those will scarce suffice to keep them warm. These changes must certainly be owing to some particles brought in the wind, which have in them the power of repelling fire.

Whatever is the particular substance in nature which is thus brought by the wind, as no analysis of the air has been yet made to ascertain it, must be left to every one to imagine and determine; at the same time taking the liberty to say, that if the air is acted upon in the same manner by the mixture of different vapours in it, with that in which water and other substances are effected, that then some account may be given of it by analogy; for that there are certain substances which, upon mixing, repel fire, is very evident from experiment.

Sal nitri in powder, mixt with water, repels fire, and sinks the thermometer ten degrees,

degrees ; borax, and sea-salt, repel fire also, tho' not so much as nitre.

Sal. ammoniac. in powder, mixed with water, repels fire so greatly, that the thermometer sunk from 47 to 28 degrees, notwithstanding the water and salt were agitated strongly by a stick, and whilst the solution of the salt was making. This proves that motion of particles does not generate heat, or that heat and motion are not the same things, unless cold and motion are the same things also.

If you pour strong spirit of nitre on ice, a cold will succeed, or the fire be repelled to 40 degrees lower than it has ever been known in nature, and 72 below the point of freezing, which is at 32 degrees.

By the mixture of fluids and solids, and their solution, it is manifest that a cold, which would extinguish all animal life, as well as repel the fire from things which were placed in it, may be instantly produced. By what means can deaths brought on by excessive cold, be so easily explained, as by this of expelling the vital heat from the animal body, in the manner it is done by these mixtures from other substances, which are placed in it.

By observations made on the thermometer of Drebellius, for the measuring the dilatation of air by means of fire, it is seen that this element of fire is continually acting by pulsations, because the air is always dilating and contracting, like diastole and systole ; and the same thing is observable in that fluid called alcohol. Whether these two motions arise from the intermitting action which is natural to fire, or to the re-action of those particles in nature which repel that element is not easily decided, as the experiments which would lead to such an examination must be attended with great nicety and difficulty.

But that exhalations are in proportion to the degrees of heat, no one will deny, provided the wind is at all times the same in its strength.

According to the degree of heat, are the evaporations more or less, which rise from the earth ; and perhaps as this phænomenon of vapours rising into the air, has not yet been very satisfactorily explained, it may not be displeasing, after having thus far examined the nature of fire and its properties, to see

see whether it will not offer some more probable solution of this difficulty.

We see that the direction of fire, tho' light comes to us from it in all directions, is naturally upwards : this does not appear to be from the same cause, that a cork put into water rises from the bottom of the vessel to the top, after having been forced down thither, that is, by means of gravitation, the heavier fluid pressing into the place, which the lighter substance of cork occupied, but from a centrifugal force, as natural to fire as the centripetal is to all other ponderous bodies ; though perhaps, in beginning with the lightest, and the tendency which those particles have upwards, or centrifugal, we may as well explain the heaviest bodies being obliged to tend downwards or rest below, as beginning with the tendency of gravitation in all bodies, which thus force the lightest upwards, but as those bodies which tend to the center, are objects which strike our senses when examined singly by experiment more strongly than lighter bodies ; and as we have given some greater reality to weight in our imagination, than to other properties of bodies ; we are accustomed to consider whatever re-

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sults from this property in matter, as having more truth in its nature than others.

Whether what has been just mentioned be true, or not, it seems very probable that fire has a centrifugal force above that which its superior levity to air would naturally give it, and does not tend upwards from other substances pressing into its place, or greater resistance given to it by the atmosphere in all other directions.

To prove this, if you pour strong spirit of nitre on essential oil, that is heavier than water, in the exhausted receiver of an air-pump ; it will instantly catch into a flame, and tend directly upward. Now in this instance, there is no heavier substance to press into its place, no atmosphere to resist its going any other way rather than this ; and no current of air to carry it upwards. This I think, proves the tendency of fire to be centrifugal, and independent of all other things and circumstances.

Whenever there is a fire made of wood, straw, or any light substance, the sparks continue to fly upwards till the fire is repell'd or extinguish'd, and then the substance which held the fire descends again to the earth ; is it probable then, that this fire added to that
matter,

matter, could extend its surface to such a degree, so as to make it much relatively lighter than the air, and to rise with such velocity? It does not appear to me to be from that cause; may it not be concluded then, that fire has a centrifugal tendency above what is the necessary result of its being lighter than air; and thence the sparks were carried upwards?

Let us now see, if this tendency of fire upwards, will not explain the evaporation of fluids, or their rising in vapours. It has been already proved, that fire is held in greater quantity by some substances than others; and the union of the particles of many of these substances, is overcome by a less degree of heat than many others; water evaporates with very little heat, as is visible by the exhalations which rise at all times when there is no frost, 32 degrees, by Fahrenheit then being the freezing point, there is some degree of evaporation it may be presum'd at 33, which is one degree warmer.

This degree of 33 being sufficient to overcome the natural attraction which there is between the particles of water to each other, or which is the same thing, the attraction of the water to these particles of fire being
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greater than to each other ; and the tendency of fire upwards being superior to the weight arising from the gravitation of the aqueous particles, it will follow, that these particles of water must rise with the fire till they meet with some power, which repelling the degree of fire in them, the mutual attraction which is natural to these particles taking place, on the repulsion of the fire, they form again into water, and descend under different appearances of dew, rain, snow, &c.

From this way of accounting for the rise of vapours, they will continue to mount till the heat in them is reduced to the exact degree of that just overcoming the gravitation of the watery particles; and during this time, the vapours will float in suspension, without either rising or falling, the gravitating tendency of the cloud, and the centrifugal force of the fire being in æquilibrium.

That there is a great degree of cold at a small distance from the common level of the earth, the snows continually known to be found on the tops of mountains, in the torrid zone, afford us an ample proof.

Thus then, the powers which repel fire being always and every where found at this distance

distance from the earth, the flight of those vapours cannot pass this bound, but being repell'd, the exhalations again descend; and thus a circulation of water is perform'd and carried from one part of the earth to the other, under the form of vapours driven by winds.

If we recur to some of the experiments which have been made on the manner of repelling fire, and consider the nature of the substances which were employ'd in it, we shall perhaps find some reason to believe, that this repulsion is probably made by the same substances in one place as the other.

First, it is remarkable, that those substances which repel fire most effectually, are such as are extremely volatile when once separated from the body to which they were united, as spirit of nitre, spirit of salt, and those which compose sal ammoniac; it is known also, that in fossile nature there are three kinds of acids, one extremely fix'd and heavy, the sulphureous or vitriolic; the other two extremely volatile, that of sea salt, and sal nitri. It is as remarkable also, that the vitriolic acid attracts fire, being mix'd with water, as strongly as the other

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two repel it; but as it is very heavy in itself, or as its particles strongly attract each other, it cannot rise into the air to any degree of height; and this shows the perfect intelligence which has constituted and appointed all things, otherwise those vapours rising in the air, would attract a heat insufferable to human nature, on their being mix'd with the aqueous vapour.

But as all the others are easily separated from their salts, especially wherever this vitriolic acid in the earth meets with sea salt or nitre; for then, the acid spirit of those two last salts rises of itself, and being extremely light flies upwards: the principles which enter into the make of sal armoniac are of the same nature, volatile in themselves, being the acid of sea salt, the alkaline salt which rises from putrefying substances of animals, and from wood foot.

These being the substances in nature, which attract cold by mixing with water, and which are of all others the lightest mineral substances, why may not this cold, which surrounds the earth at the distance of two miles or less, perhaps arise from the mixing of these mineral effluvia with the
aqueous

aqueous vapour ; and thus, upon any sudden or greater degree of them arising than usual, the vapours are condensed into rain, hail, or snow, and descend again to the earth. This seems explaining the phænomena of evaporation, rain, hail, and snow, according to the obvious manner in which they appear to our senses, and agreeable to the known properties of fire, water, and the repellents of fire just mention'd; and according to the perfect wisdom of the maker of all things, where the cause of exhalation being heat, this very heat is corrected by the vapours which it rises; and thus an equilibrium in great measure preserved.

That more vapours are exhaled when the wind blows stronger, than in still weather, the heat continuing the same, perhaps may be owing to this: when the wind blows briskly in passing over the face of waters and moist places, it carries off the aqueous particles along with it ; or by detaching one particle from another, and overcoming their mutual attraction, a less degree of heat is capable, after that, of carrying them into the air upwards.

Whatever may be the efficient cause of this cold, the final reason of it is manifest enough ; for unless the vapours were condensed in this region, and the fire repell'd which bore them up thither, the whole element of water design'd for the use of this great globe had been exhausted and carried off with the particles of fire, which for any thing we know to the contrary, after being repell'd, continue to return to the sun, and thus a circulation of heat is carried on between this orb, and that from whence it draws its vital heat and motion ; and perhaps this may add some probability to this conjecture, that tho' since the hour of the creation, the sun has been eternally shedding his beams on this globe, and millions of space equal to it, yet it has not decreased its own size, as far as natural philosophers and astronomers can discern, or augmented this or any other planet, and that the sun-beams, tho' ever so fine, are still matter, those that will not be convinced by their feeling, may by this experiment.

Take a very delicate watch-spring, before it is coil'd, and place one end of it in a vice, letting it stand upright above the vice, then
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take a dioptric burning-glass, and direct the solar rays so as the focus may fall on the upper point of the spring, and you will see it put into a vibratory motion by the sun-beams.

There are yet three other substances which very suddenly extinguish flame, and which are very generally dispersed thro' the atmosphere; these are first, the gas or vapour which arises from mines, and repels or extinguishes the vital and common fire at the same time in the workmen, and lights which are in the mines.

The second is that exhalation or vapour which arises from putrid jakes, which have not been for a long while open'd, and which flies out on opening; this destroys the workmen, and repels the flame, or extinguishes the lights.

The third is that which arises from the juices of vegetables in fermentation, which is so great in the large distiller's work-houses, that a man, or any other animal that should pass near the great vessel which they call a back, when the liquor is in its highest fermentation, would instantly fall dead, and the largest torch is momentarily ex-

tinguish'd by being past thro' the exhalation, and the fire totally repell'd.

From these three vapours, so similar in their effects, it is probable, many diseases of the worst kind take their rise: this shall be farther explain'd when we come to assign the causes of diseases, and the method of cure in consequence of them; for tho' they seldom appear enough at any one place on the surface of the ground, to produce effects so sudden and violent, as in those places just mention'd, yet are they frequently dissipated thro' the air, or two of them are generated in the stomach or other parts, in a quantity sufficient to lessen the degrees of vital heat, and bring on disorders in consequence of that diminution.

C H A P. XIII.

Of Diet, and its different Effects in augmenting and decreasing the animal heat.

FROM what has been already said, it seems that fire in its different degrees, is the sole active cause in nature, which imparts life and health to animal and vegetable beings; but at the same time it must be acknowledged, that tho' fire is the only active principle in nature, yet that the aliment of one class of beings, and the soil of the other, contribute greatly to make the crassamentum of the blood, and the juices of the plant in greater quantity, and more adapted to the sustenance and well-being of each order, as well as to the attracting the vital heat, which is necessary for the existence of each, from the earth.

If health in animal bodies depends so much on the diet, no enquiry can be of more consequence than that which leads to the knowledge of what food is most proper for mankind, and what is the most natural for animals whose stomachs are form'd like

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that of human nature; in knowing this when the blood is broken, or any ways disorder'd, when the animal heat is diminish'd, we shall arrive by the shortest method to restore the crasis of the blood; and the degree of animal heat which is necessary for health, and in all ardent states, when the crassamentum is in too great quantity, or too adhesive, and the animal heat above the degree of health, we shall learn the shortest way to lessen the quantity and adhesion, and reduce the vital heat to the degree of health; by this way of proceeding we shall be inform'd, in what manner the quantity and qualities of the blood may be diminish'd, encreased, or changed, and not prescribe promiscuously all diet, under the denomination of that of easy and difficult digestion, without having first consider'd what it is which constitutes the difference; for certainly the food and disease ought well to be consider'd before we ascertain the diet of the patient.

Upon the regulation of our diet depends our health, and the success of our practice in the cure of diseases in great part.

According to the soil also, in a great measure, is the vigour and growth of the plant

which is set in it, and the animal improves or suffers in proportion to the aliment which it takes being adapted to its nature or not.

Some diseases, and some stomachs, in consequence of those diseases, require a very different diet from others; whatever therefore leads to the discovering these differences, and ascertaining the diet which is fittest for those that are afflicted with these disorders, must necessarily conduct us to the cure of the sick, and success in practice.

The best way, as it appears to me, to come to a just decision of this important part of knowledge in medicine, is to trace nature, and the path which she takes in the first formation and support of an animal; and then by the analogy or difference which is to be found between the two different species (for in this instance two classes is sufficient) the granivorous and carnivorous, conclude what is by nature most adapted to mankind; upon this will depend the discovery of what is to be denominated of easiest digestion, during the increase of the human creature.

Animals then may be divided into those that live on vegetables, and those that feed

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on meat, tho' there are animals which live promiscuously on both.

As the order of beings arises in nature from the mineral to the vegetable and animal, during the operation of heat on the particles, and their passing thro' the tubes of each of the two latter species, their substance becomes more assimilated to our natures, more nutritive, and more easy of solution.

The mineral part affords nothing nutritive directly from itself to human nature, and yet a thing so small as a pin's point, the seed of a plant, shall draw nutrition from this indigestible earth, and transform it into animal food in great quantity, so as to contain many thousand times as much matter as it had originally.

Again, from the animalcule in animal nature, what prodigious increase of size in a little time? But this order of beings receives all its nourishment from animal juices, I mean all that are of any size during its first growth from the animalcule, and after that, converts the vegetable into the animal nature.

Thus

Thus, in the vegetable world, the process and growth of vegetables, converts the parts which are found in the mineral world, and assimilates them to their own nature, by passing them thro' their vessels, and the animal again, by passing those vegetables thro' the degrees of heat, from 96 to 107, according to Farenheit, and thro' the tubes of animal bodies transforms those particles into animal substance, totally changing their former nature.

Mankind is by nature design'd, or custom led, to live on a mixture of animal and vegetable food, and in general those of our species who are in health, live in this manner, and are the better for such a mixture of diet; but when the stomach has received any disorder, or any disease afflicts us, it is then of the highest importance, to know what food chiefly opposes the state and condition of the vitiated humours in our bodies, or is least liable in nature to be converted into similar fluids; what may reduce the vital heat, when it is carried too high, and heighten the degrees when it is fallen too low; this is of much importance to the valetudinarian, and physician.

It will be allow'd, that different foods produce different effects in an animal's stomach; that vegetable productions, many of them will ferment and become sour, and some of them will become alkalescent. Animal substances are incapable of the first, and always verge towards putrefaction, as it has hitherto been said; but in fact, the different effects of the different degrees of heat on animal substances deprived of life, have not yet been sufficiently distinguish'd; the change which substances undergo in passing the intestinal tube of persons in health, is not from a sound state to a putrefactive, but to a sterchorous, a thing as different from putrefaction in its effects as possible, the first being a poison, and consequently would be fatal to us; the other sanative, and necessary to our well-being and existence.

This indeed, the odour which rises from the intestinal evacuation, will convince us of, that of sterchorous being as different in its scent from the putrefactive, as a rose from a jonquil, tho' not so sweet; and as the odour differs, so does the secretion. The discovery of alkaline salts by chemical experiments in all these substances promiscuously, is not a
sufficient

sufficient proof of their being all alike in themselves, or in their natures and effects on human bodies, any more than finding fix'd alkaline salts in all vegetables by calcination, proves them all alike in their dispositions and effects ; there is more precision requir'd in determinations of this kind, than from what is universally discoverable in all animal substances, putrified or not, by one degree of fire or another ; there is, it seems, some part of animal substance which naturally becomes alkaline salt, and volatile in all degrees of heat ; and there are other parts of it which become putrefactive, and producing poison within certain degrees of heat, and sterchorous, and affording aliment within others ; thus the degrees of heat are of the utmost import to be ascertain'd in every patient.

It is a most displeasing, but very useful part of the practice of a physician, to examine what is the nature of the intestinal discharge, yet it is as necessary, and perhaps may tend as truly to the explaining the disorder, and effecting its cure, as the pulse, or any other common manner of enquiry.

There is no question oftener ask'd of a physician than this, What food is easiest of di-

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digestion? and it is as often answer'd contradictorily: some asserting the vegetable, and some the animal food; this however, can never be ascertain'd, if it be applied to particulars, without knowing the disorder and constitution of the person who consults you; and this is as well to be known by a physician who understands his profession, and the collateral knowledge belonging to it, the first time of seeing the patient as at any other: every human creature has not a distinct and separate constitution, different from all other individuals; it has indeed, a constitution distinct from all those who are not of the same heat and temperament with itself; but this is general to that class, and known by general symptoms.

A person of taste and judgment in the general rules and objects, knows the excellency of the finest arts, of a statue, or picture, the first time he beholds it; but of those who have neither of those faculties, it may lie whole ages before the eyes, and yet its excellency and beauties remain undiscover'd; it is from general principles that things are understood, and not from something particular and singular in each object; where

wherever beings of the same kind may differ in particulars, yet they resemble one another in the whole, much more than they can be unlike; and whoever knows the general causes will not be long unacquainted with the little deviations of symptoms in different persons.

But if, in asking this question, what food is easiest of digestion? they mean, what is most easily converted into nutriment, when the body is weak, or what substance is most easily consubstantiated with the human body, that may be answered perhaps.

The best way, as it seems to me, to discover and ascertain this, is to proceed from the first formation of an animal, to see what food gives it its beginning and increase; and then compare the make of the stomachs of those animals who live on herbage and grain, with those which feed on animal substance; and the process which vegetables must pass thro' to be transmuted into the animal nature, in the bowels of those creatures which are graminivorous and granivorous, with that which animal substances undergo in passing the intestinal tube of those which live on animal diet. By this we may at last, by the analogy

logy which the human species has in conformation and digestion with either of these differently nourished creatures, find something to explain the nature of digestion, or what food is fittest in general for human-kind.

All animals during the time of gestation in the womb, incubation, or artificial heat applied to the egg, are solely nourished and sustained by animal substance; and to this it owes its whole encrease till it comes into the world.

This is equally true, whether you suppose the foetus nourished by the liquor it swims in, or by the blood passing from the mother to the foetus, and from the foetus to the mother, by means of the umbilical vessels; in oviparous animals there can be no doubt of the truth of their foetus's receiving their whole encrease from animal substances. This rule then, is universally observed in all animals, whether viviparous or oviparous, granivorous, or carnivorous; and this seems to afford an unanswerable argument, that animal substance is much easier converted into the increase and growth of animals than the vegetable.

Another

Another reason, which offers itself, that the above observation is well founded, may be collected from the steps in which nature proceeds to accustom animals which live either altogether on herbage and grain, or on the mixt diet of vegetable and animal, to the use of vegetable food.

This is done in quadrupeds and in human-kind, by preparing them a particular food which contains the mixt principles of the animal and vegetable world ; and which is to sustain the new being just come to breathe ; this fluid is milk, which containing in itself the above mixture of the animal and vegetable nature, which is administered to the infant when it has more strength than when in the womb, and adapted to the accustoming this new creature to a diet more difficultly digested and assimilated to its own nature.

That milk is of this mixt nature, its turning acid in one part, and alkaline in another, sufficiently evince ; and if this fluid thus prepared for the new-born creature, had been as easily converted into animal substance as the white and yolk of an egg ; the same perfect intelligence which enclosed these two substances within the shell of an egg, or the
liquor

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liquor within the coats of the chorion and amnios in the womb, at the first formation of all things, could with equal ease have directed and destined that fluid called milk to either of these places.

But as this has not been directed in that manner, it may be concluded that a mixture of vegetable diet is more difficultly transmuted into animal nature, than the animal substance itself ; and that things were ordered in this manner for the above reason, to habituate the young animal to a diet of more difficult digestion, than that substance of which it was first form'd.

As a farther proof, that vegetables are not so easily converted into aliment in their own nature, as animal substance ; let us examine the method which gramenivorous and granivorous animals digest and prepare their food, and the parts in which they differ in formation from carnivorous creatures.

This will lead us to a more explicit proof of the truth of what has been already said.

First then, those quadrupeds which live on grain and herbage, have several cavities in the intestinal tube, which answer to so many stomachs in the carnivorous animal ;

and the aliment which they take is much longer in passing the whole length of that tube, than the aliment which is taken by human creatures; this is known from the length of time in which a horse must retain the purging potion in it before it begins to operate.

Next, those animals who ruminate, afford another proof of the difficulty with which vegetables are reduced to animal sustenance and digestion. The power of bringing the food up again to be farther communicated by mastication, that it may lie closer together in the stomach, and approach nearer to the nature of putrefaction, than fermentation, which is the case in digestion; for, according to the quantity of fluid contained in vegetables, will the effects be either of the fermentative or putrefactive kind; not but that the saliva being by this action of ruminating mixed with the vegetables, will much promote the disposition of them to become alimentary.

This action then of ruminating, the cavities made for the detension of their food, where in larger quantities a more thorough change will be made in it, than where it is found

found in smaller; the time it takes in passing through the body; all coincide to form an argument, that vegetables are more difficultly transmuted into animal nature, than one animal substance digested, separated, and prepared for the supply and support of another.

But let us examine the different formation of the stomachs of those animals of the same genus, who live, one species of it, on animal food, and another on vegetable; this will farther show us, that the digestion of the carnivorous bird is performed with more ease than that of the granivorous; and that infinite wisdom has form'd, and disposed the organs of each animal according to the food which the species was destined originally to live on.

To decide this, nothing can lead us so fairly as those experiments read to the academy of sciences at Paris, by *Monf. du Reaumur*, the most accurate observer and most faithful relater of physical experiments, at the same time, perhaps, the best reasoner on the phenomena they exhibit, and the most able to carry them into use of all those who have hitherto pursued the study of natural knowledge.

This

This gentleman, after having first said, that the stomachs of different birds are very different in themselves ; some of them being muscular, thick, and strong, called gizzards ; others thin, membranous and large like a pouch ; a third sort in one part strong like the gizzard, and in another part membranous ; a fourth kind of a nature between the muscular and membranous stomach, in order to decide whether digestion was performed in the stomachs of birds by trituration or digestion, forced turkies to swallow tin tubes, closed at each end, and covered with fodder very strong ; of these, on opening the birds, he found some indented from end to end, others flatted, and some of them had been so violently press'd, that the fodder was gone and the tin partly unrolled ; he found also, that by the experiment of hanging a weight on the handle of a vice, and putting other tubes of equal strength between the cheeks, that the force with which similar effects were produced on these tubes in this manner, to those tubes in the gizzards of turkies, was equal to the pressure of a weight of almost four hundred and an half ;

and thence he infers the great force of that stomach which is commonly called a gizzard.

After this, Mr. du Reaumur having made three leaden tubes open at each end, into one he put a grain of raw barley, into another a grain with the husk taken off, and into the third a grain of boiled barley; then he forced them into a turkey's stomach; these tubes, after having remained twenty-four hours in the gizzard of this fowl, were taken out, and the grain was found entire and unchanged in each of them.

It is well known, he says, with what ease ducks digest animal food, and in how little time; for this reason Mr. du Reaumur put little bits of flesh into leaden tubes like the former; these tubes, after having remained several hours in the gizzard, were taken out, and the flesh found exactly as it went in, unchanged in weight, smell, or consistence.

Birds of prey are those whose stomachs are most like the human.

For this reason, Mr. Reaumur forced into the stomach of a hawk, whose stomach is membranous, a tin tube; after having retained it twenty-four hours in his stomach, it was rejected

jected by vomit (which is common to birds of this kind, when they cannot digest any thing which they have swallowed) and not the least mark was found either of pressure or trituration on the whole tube.

He then put into tin tubes little bits of raw flesh, which were secured from coming out, by thread wound round from end to end, crossing each other at the center of the apertures: these were given to the hawk; and after twenty-four hours, when the tubes were examined, the meat was found dissolved in them, and the threads not in the least disordered or rubb'd by the action of the stomach. In the center of the flesh indeed, there was a very little bit, about the eighth part of the whole, which, after being cleaned, remained flesh unchanged.

Not content with this, he placed bits of chicken bones in tin tubes, in the same manner as before, and thrust them into a hawk's stomach; in twenty-four hours, when the tubes were vomitted up again, these bones were entirely dissolved.

He repeated the experiment with ox-bone, the very hardest parts only, and found that after being three times thrust down into the

stomach of a hawk; they were dissolved also. During the making of these experiments the threads which were wound round the tubes to hinder the bones from coming out, were not in the least rubb'd or disordered.

After this, he put into tin tubes grains of boiled barley, dry barley, and a bit of bread in separate tubes; these, after having staid twenty-four hours in the stomach of the hawk, upon being rejected by vomit, were found to contain the bread and grains unaltered: a piece of pear was put in a tube and served in the same manner, after having staid in the stomach twenty-four hours; upon being examined it remained unchanged.

Thus then it plainly appears, that all vegetables are more difficulty dissolved and digested than animal food: the duck, which eats either one or the other, though more adapted by its conformation for grain, yet digests animal substance in a much less time than it can grain; and those birds whose stomachs resemble ours, dissolved bones with great facility, tho' bread was left untouch'd, and even so tender a substance as that of a pear.

What-

Whatever be the solvent in the stomach, it plainly appears, that meat is its proper matter to operate on, and vegetables not at all; from thence, by analogy of the stomachs of these birds resembling the human in their make, we ought to conclude that animal food is the best adapted to our nature also.

Perhaps there is no more required to perform this solution of bone, than that the stomach retain the vapour of its fluids, as in Papin's digester, where the like substances are easily dissolved by the cover being screw'd down tight, so that the vapour cannot escape in boiling.

We are apt to imagine, that hard substances are more difficultly dissolved than soft, but a little attention shows us that the menstruum being adapted to the subject, hardness has nothing to do in it: ol. vitriol dissolves steel, and yet does not touch wax, and oil dissolves wax, and does not touch iron; and so in a thousand instances.

Let us now consider the nature of the aliment itself, the vegetable and animal.

It has been already said, that the alteration which aliment of all kinds undergoes in the stomach, and passing the intestinal tube,

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was not into putrefaction, but into the sterchorous state ; this last, however it may differ from the putrefactive, is yet more a-kin to it than to the fermentative, as in some degree the same contents may be found in it ; and as the seeing in what manner the putrefactive change is produced in vegetables, may lead us in some degree to the explaining that of the sterchorous ; let us consider what are the requisites indispensibly necessary to produce the first named change in the vegetable kingdom.

The vegetables must be gathered in the summer-season, bruised and pressed tight into some vessel, and left open to the air ; after this by degrees, in the course of several days, the heat beginning in the center, the mass grows hotter and hotter till it comes above the degrees of boiling water.

The more this herbage is compressed, and the less aqueous particles remain in it, provided it is not quite dry, the greater will be its degree of heat, when at the highest ; after this, it grows colder by degrees, till it settles again in that of the atmosphere. By this process the whole mass is changed into one uniform pulp ; this happens alike to all
kinds

kinds of herbs, whether insipid like grafs, alkaline as scurvy-grafs, or acid as sorrel ; in thus passing through all the degrees of fire, which are necessary for its being converted into the putrefactive state at last, it sends out very various odours ; at first its native smell, then that of wet hay succeeds, those go off and then a sterchorous smell, and lastly, a putrefactive.

In large quantities, hay is often known to break out into flame, if the moisture in it be but little ; and according to the degree of moisture in a plant laid aside, and the degree of pressure, it either becomes putrid or mouldy ; but after having pass'd all the above process of heat, it remains at last a putrid pulp, resembling in all respects the gangrenous tubes ; and by how much the animal is hotter in degree who lives on vegetables, by so much the more the secretion by the intestinal tube resembles this gangrenous ichor.

In this account, which is copied from Boerhaave, you see that to finish the whole process, it is necessary that the heat rise above that of boiling water, or the putrefaction of vegetables will be imperfect ; whereas, to make a thorough putrefaction of animal

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substance exposed to the open air, the heat should not rise much above seventy-five degrees to make it perfect : the animal heat of health will dissipate the more volatile and aqueous parts, and dry the substance, and in the fermentation of vinous liquors the same degree is the most favourable, a few degrees above 75, making wine and even vinegar vapid during the fermentation.

Here it seems that the passing of vegetables through the action of digestion ; and being changed into the animal nature, expedites the power of their becoming putrefactive, as the animal substance begins to putrefy in the degree of 33, though it does not arise to its perfect state till it arrives at that of 74, and cannot be prolonged or produced in substances open to the air above that of 94.

Whoever will attend with diligence to this process of vegetables passing through all the different degrees of heat, till they return to that of the atmosphere, and terminating in a kind of gangrenous fancies, will find that the stercorous odour is that which it takes in its highest degree of heat, and the putrefactive in its decline ; the transition from
one

one degree to another, in its ascending the scale, being too quick to permit the putrefactive state, the sterchorous takes place ; and in the descending degrees nothing forbids the putrefactive state to exert itself ; and during this last, it is that the vegetable is converted into the appearance of a gangrenous sanies.

This distinction is of the utmost consequence to be made by all physicians between the effects of different degrees of heat on these substances, whether in the vegetable or animal kingdom ; a less degree of heat will produce putrefaction, then the sterchorous state in animal substance, and in vegetables, unless the sterchorous state be first produced (which answers to the vegetable's being converted into animal substance by the action of digestion, circulation, and assimilation, by animal powers) there will be no putrefaction in the process, but it will remain in a quite different appearance and condition.

Thus then, to produce the sterchorous state in animal and vegetable matter, it is absolutely necessary that the heat be above the degrees of 74 ; and when it mounts to that of 96 and 98, putrefaction can never take place

in the human body ; each degree of heat has its certain effects, the one produces putrefaction, the other alimentary and stercoraceous fluids, as one degree produces crude and unripe juices in the grape, whilst a superior degree, either by nature or art, improves, ripens, and exalts the watery juice into a rich and vinous fluid.

That vegetables are not so proper a food for human kind, may in some measure be learn'd from this, that many of that kind, which enter into our common manner of living, pass through us unaltered, as carrots and nuts ; others again create flatulencies, which are almost insupportable to many stomachs.

The quantity which is necessary for supporting an animal that lives on vegetables, must be much greater than that which is devoured by the carnivorous ; a sheep eats a greater weight of herbage than a large dog does of meat.

Thus then it seems, that animal food is much easier digested and transmuted into animal substance, by the human powers of digestion than the vegetable ; and this plainly appears, if you begin from the first moment

ment of the foetus increasing in the womb, where, till its coming into light, it is form'd entirely of animal substance.

If you compare the fashion and shape of the intestinal tube of granivorous animals with those of carnivorous, you see that in the first, there must be a stomach provided extremely muscular and strong, replete with little stones or things of that kind, to grind the grain for digestion ; or it will pass almost unalter'd, and young chickens must have little animals just after their being hatch'd to live on, or there will but few of them survive, because they cannot digest grain.

In the granivorous, there must be more receptacles to retain the vegetable, than are in the human bowels ; it must be in greater quantity also ; and other animals again by ruminating, prepare it to undergo the alterations which it must pass thro' to become alimentary.

Again, the vegetable food of itself, in all respects, requires a greater degree of heat than animal substance, and more time to undergo these changes, in nature necessary for its being nutritive ; as is seen in oxen, sheep, &c. which are hotter than humankind ; a
duck,

duck, as has been already said, will digest animal food in the tenth part of the time which it does grain, and the human stomach cannot digest many of the vegetable tribe at all.

In the experiments on putrefaction, in vegetable and animal substances, the former requires a degree of heat three times as great as the latter to change its nature, the first being above 212, the latter being 74.

Thus then, whether we begin from the general formation and encrease of all animals in their first state, or examine the similitude or difference between the make of the intestinal tube of granivorous and carnivorous animals, if we observe the ease with which bones are dissolved in stomachs, where bread and barley are left untouch'd ; the process which vegetables must undergo to be changed from vegetable to animal nature, in the ruminating and other granivorous creatures, the different degrees of heat necessary for one more than the other, to effectuate the same changes ; all these conspire to prove, that animal diet is the easiest in its own nature, to be digested and assimilated to animals, especially in all weaken'd states,

I say nothing of distill'd liquors, these will be mention'd in the article of the operation of medicines; the alterations which are felt in the stomach from acidities, after having drank fermented and fermentable liquors, arising from their passing from vinous to acetous fluids, is so easily discover'd and remedied, if the patient will have resolution to continue a diet which every physician that knows chemistry enough to understand what substances are convertible into acids, and what not, can prescribe; that there needs no delay on that account.

What has been said, may, I think, decide on the use and abuse of vegetable diet, and discover the preposterous method of prescribing such a regimen to patients of cold pituitous, nervous habits, who want most nourishment from least digestion, and smallest quantity of food; and of all those which Dr. Cheyne has condemned to the torments of a vegetable regimen, which he did indiscriminately to all, I never knew but one who did well with it, and he was of a hot and acrimonious habit; and even in this case the milk perform'd the greatest service, and was the greatest part of his diet; the
oily

oily parts of that fluid mixing with the salts, gives them a kind of neutral state, or rather saponaceous : by this means they are render'd less caustic, and pass off more easily by the urinary, and other secretions.

This gentleman excepted, I never knew one of his patients who look'd like other men ; nothing is so easy to distinguish as a vegetable man, by his physiognomy, the fittest appellation by which they can be distinguish'd ; he neither looks, talks, or moves like other people ; his face conveys a declaration of his whole body being out of order, by the lifeless insipidity which is in it, as his conversation does of his mind being disturbed, his whole time being taken up in recounting to the world his manner of living, his feelings, his stomach, his sleep, his watchings, how many pair of stockings and under-waistcoats he wears, how often he changes shirts, and every ridiculous particularity of his whole life ; if he pretends to have spirits, it is no more than a certain equability of a lifeless inanimate state, like that of the dormouse amongst animals, or the yew-tree in winter amongst vegetables ; the warmth of one, and the green of the other,

other, just show they are alive, with this difference however, that the summer will wake the two latter into actual life and motion ; whereas, to the man of vegetables, the summer never comes, that comes to all ; and the very power of vegetation and recovery from sleep, which is bestow'd on the plant and dormouse, are forbidden him by the regimen he pursues.

In fact, either Dr. Cheyne did not understand what he was about, in this regimen, which he so universally prescribed, or he created a new kind of bubble, different from all those of the other stock-jobbers in the alley ; and if he did not understand the animal œconomy, nature of digestion, and what food was fittest for human kind, to reinstate and continue health, he knew perfectly well how to apply to the faculties in the human mind, those objects which influence the belief and actions of men. Being convinced that the love of novelty and singularity, together with that superstition which actuates the minds of people who have been long ill, and found no perfect cure, have great sovereignty in determining their resolutions ; he skillfully hung out a bait to those dis-

I positions

sitions in human nature, and contrived a regimen and diet which would neither cure nor destroy, but reduce them to an æquilibrium between health and sickness; at the same time knowing, that every valetudinarian feels some alteration in himself at spring and fall, and the weakest the most, he was sure twice a year to receive the letter and the guinea (being a true Swiss, no penny no pater-noster) from every devotee which he had seduced over to his sect: this, on a moderate computation, must be four hundred persons in this island of whimsical inhabitants: these again, like all the sectaries in religion, were as fond of converting others to the destruction of their health, as the devotees are the minds of those they attack to distraction; and thus the doctor had no small herd of victims sent to be sacrificed yearly at his altar in Bath.

If you tell me, Dr. Cheyne was in earnest, because he practised the same on himself, I say, that people act false, in the same manner that they say false long enough till they believe it to be true; or in this way, as well as in the poetic, the same rule of Horace will hold, *Si vis me flere, dolendum est primum ipsi tibi.*

This

This then, was the bubble which he begat, and too many have been his dupes and sufferers, for their attachment to that knowledge of human nature which was superior in him, to his skill in his profession.

All that has hitherto been said, is not with a view to depreciate the use of vegetable food entirely, but to ascertain only what in debilitated states is the properest restorative diet; in perfect health, a mixture of vegetables is in some degree requisite, and in ardent fevers in the beginning, absolutely necessary; because at that time nutrition is not the thing proposed, but almost the contrary.

At these times it is of use, but in debilitated states, in low nervous complaints, cold and watery habits, it is the very destruction of the little health and vitality which remains.

Milk, however, is of another nature, as it includes a mixture of the animal and vegetable principles; and in states, where the animal force is not too much diminish'd, nothing can be a more proper food; yet I have observed, that after long and terrible fevers of the worst kind, where the understanding

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as well as the bodily powers, have greatly suffer'd, nothing recovers the strength and vigour of the sick so soon as broths made of animal food, provided the fatty substances are stript and separated from the meat before it is boiled; and in thus proceeding according to the different degrees of the vital powers being exhausted, in adapting the diet of the sick, we follow the dictates and ordinances of that power which never errs.

In all our choice of animal food, there is much less reason to be curious of the kind, than amongst vegetables, nothing requires more attention than the last; the effects of animal substances in the human stomach, are ten times more similar than those of vegetable; there is infinitely more difference in the effects of cabbage and sorrel, onions and spinnage, garlick and turnips, than in those of beef and partridge, venison and chicken. What has been said, it is hoped, may decide the preference of animal to vegetable food in weaken'd constitutions, and offer reasons to determine when each diet is to be pursued and prescrib'd.

I know there are many alterations which arise in the stomach from various mixtures of the vegetable and animal kingdom, which occasion complaints, in their nature, stubborn and painful, yet however, by strictly attending to the symptoms of the disorder, it may be easily discover'd to what part of our diet these complaints are referable, and then an abstinence from that part, and some medicinal application, generally sets all right again; and from what I have been able to observe, the abstaining from vegetable food, has been nine times in ten at least the readiest way to obtain health, and this I think, appears from manifest reasons, in consequence of what has been already said.

C H A P. XIV.

Of animal Secretion.

AFTER having endeavour'd to settle what food is easiest of digestion, from the different natures of animal and vegetable substances, and from the greater analogy there is between the stomachs of mankind, and of carnivorous animals, than between those of the graminivorous or granivorous kind : Let us now enquire by what means the secretions are made in the human body ; for unless these are regularly and truly discern'd, the state of our health must be greatly impair'd. In the vegetable world, if the perspiration of a plant be stopt, it immediately becomes sickly, and soon dies ; and even in the case of incubation or heat, applied to the hatching of chickens, if the egg be cover'd with a varnish, and the pores obstructed, so that the perspiration cannot pass thro', the egg never produces an animal, but becomes filled with a fætid sanies, as Mr. du Reaumur has shewn in his experiments.

It has been already said, that by the application of 98 degrees of heat, or a little more, according to Farenheit, to an egg for three weeks, there comes forth a perfect animal, form'd from the white of the egg; and from the best inference on my own observations, as well as from the experiments and reasoning of others, I am inclined to believe, that the foetus is form'd from the liquor in which it swims in the womb; also.

Now, as the serum of the blood has been form'd out of the red globules, which was transmuted into that substance from the chyle by the heat of 98 degrees, acting on the contents of the intestinal tubes; and as this serous fluid resembles the white of an egg in every manner of examining it, the same degree of heat which form'd an animal from this similar fluid in the egg, continues to supply and sustain the animal substance and being, from that humour, the serum: every degree of heat which exceeds this of 98, or of health, or falls below this point in human nature, does therefore in proportion change, lessen, or increase the animal secretions, and in proportion also to these

alterations, will be the state and condition of our health.

The more effectually then to restore a person from a state of sickness to that of health, from burning to temperate, from languid to active, from cold to warm, is to know by what means the first may be reduced in degrees of fire, and the latter exalted; and whenever the true heat of human health is restor'd, every secretion will be truly prepared, and take its due course, provided the viscera are sound.

Now, tho' the method of diminishing heat, or augmenting it, may be known without a thorough knowledge of the manner in which the secretions are made, and the salutary result from the alteration of this vital principle follow in consequence of it; yet as what has been hitherto assigned as the cause of those different fluids being separated, appears to me to be absolutely erroneous; it may not be amiss to explain, in what manner they are form'd and separated from the blood. Every additional discovery of this nature must add more or less to the perfecting the art of healing, and the slow advances which have hitherto been made in it,

have

have caused that fluctuating and indecisive practice which has so long prevail'd.

There is no instance in all physiological philosophy, perhaps, where mechanic laws and mathematical reasoning have been more erroneously applied, than in explaining the doctrine of secretion.

It has been said, to explain these phenomena, that where different bodies are projected with the same velocity, their impulse on others will be in proportion to their density or quantity of matter, under a given surface.

Hence it has been inferr'd, that the particles of the blood, moving all by the same force of the heart, those will continue their direction nearest to a strait line, and move with the greatest velocity, which have the least surface and greatest weight, or the velocity of each globule will be in a ratio directly as the density, and inversely as the surface; that is to say, if one globule be twice the weight of the other, it will from the same impulse, pass over double the space in the first instant, and in the second instant, twice the space of the other; from this it follows, that the distance of those different

particles will continually increase as the times.

It is a little difficult to imagine, how philosophers could apply this manner of reasoning to the particles of the blood in motion, as above, if they had attain'd to the least intelligence of the state of that fluid in the sanguiferous vessels. Was this reasoning true in its application to the blood's motion, in the manner already mention'd, it would follow, that in every quantity of blood thrown out of the heart at each systole, into the aorta, the red globules being heavier than the serous, would move quicker than the serous, and thus arrive sooner at the end of the aorta, where it begins to branch off into other arteries; and for the same reason, that those red globules move quicker than the serous, they will also continue longer in motion, and thus the distance between the red globules of the blood and the serous, continually increasing, it must happen, that upon repeated circulation, the red globules and serous will be totally divided, each having a different momentum from the same impulse.

But that this is not the fact, we are led to a demonstration from the common operation

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tion of bleeding, where the due mixture of the ferous and red globules always come together at the orifice, and not at one time ferous, and at other moments red globules, which would be necessarily the case, if the projectile power operated on the different particles of the blood, as it is above assign'd.

Thus then, it must be allow'd, that this law of projection is not true in this instance, or that the heart is not the whole projectile power which moves the blood, which I believe has been already very evidently proved in the former chapters.

In truth, the motion of the blood is compounded of the direction given it by the heart, which is progressive thro' the arteries and veins; and the second given it by the arteries, which by their contraction lessening the diameters of their circles, determine the particles of the blood equally from all sides, to the center of their axis, and thus the blood is duly mix'd, and the progressive motion continued.

To explain the reason also, why the ferous and colourless particles of the blood are separated from the sides of the arteries, it is again said, that every body in motion endeavours

deavours to procede in a direct line, unless the direction receive some alteration by some other power or assistance, and this endeavour will be always as the moving body is denser ; so that in a mixture of particles of various specific gravities, moving by one common impulse, the heaviest will keep on their course nearest to the direction of a strait line, whilst the less heavy recede laterally or obliquely, from their first direction.

To instance, if you discharge from a wind-gun a small globe of gold, another of wood, a third of cork, and a fourth of a bladder inclosing air, placed in this order in the gun, the gold will go on in a strait line, and force the other three off laterally obliquely, in proportion to the gravity of each spherule ; from this it is inferr'd, that amongst the component particles of the blood, the heaviest are driven in a strait line, and the lightest forced to the sides of the arteries, and by that means into the lateral orifices and glands of secretion.

In answer to this, we observe first, that where the lateral branches of an artery go off from it in an acute angle, if the great branch continue strait on in its former direction,

tion, that the orifice of this separating branch, is equally lateral with all those other arteries that go off in right or obtuse angles.

But if the branch does not continue to go straight, or in the same direction, the quantity of the red globules which will pass into the new branch, is in proportion as this branch is farther or nearer from a line drawn thro' the axis of the undivided trunk, between the separating arteries; so that if this line was equidistant from the dividing arteries, each would receive a quantity of red globules, in proportion to the diameter of their two tubes.

But to give fair play, let us imagine that the angles in which lesser arteries go off from the greater, which last still proceed in the same direction as before that division, do really make some alteration in receiving the different particles of the blood, beginning with the most acute. and proceeding on to the most obtuse.

Then it will follow, that the vessels which go off at the most acute angles, will receive more red globules than those that go off at right angles, and those again, than vessels going off in obtuse; and yet the contrary of
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this is universally found to be true, all the arteries in the human body, at whatever angles they divide from the greater trunks, having the same proportion of serum and crassamentum found in equal quantities of the blood drawn from them: thus this manner of reasoning has no more truth in it than the former, and affords no satisfaction in the manner of its explaining how the colourless fluids pass off by secretion.

In fact, wherever there is a perfect mixture of particles, as in a solution, these phænomena arising from the properties of heavy or light, are totally destroy'd, there is great reason to believe, that all bodies are equally heavy in their minutest particles; because where resistance is taken away, as in the exhausted receiver of an air-pump, the feather and the guinea fall in equal time to the bottom; and in a solution of sublimate mercury in water, the particles of the mercury do not subside, whilst they continue without the sphere of attraction of each other; thus tho' mercury in the undivided state be fourteen times as heavy as water, yet reduced by solution to its minima, the particles are no heavier than those of water.

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It seems indeed, that strictly speaking, (as it is according to the metaphysical and abstract idea of matter) that there is no such thing as different specific gravity in the ultimate particles of bodies ; but that the whole difference of weight arises from the combination and different degrees of proximity of those particles, it is, I think, more than probable, that the particles never touch each other in the most solid bodies ; if the contrary be supposed, a very obstinate difficulty will arise in the conceiving how the surfaces of bodies are lessened by cold, or how more particles can be included in the same space, which before held as much as it was possible ; and yet this must be said, if you suppose that those particles were in contact in their minima before the increased cold.

However, to prove whether in the state of solution a heavier body, such as mercury, would move quicker than the water in which it was dissolved : I caused a tube of leather to be made with very small holes oneach side, half inch distance from each other in respect to the length of the tube which was ten foot long, and as near as possible to one another circularly.

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Through this I injected with a large syringe, a solution of mercury sublimate in warm water, impregnated as much as it could sustain; then examining the fluid which pass'd out of the lateral holes at different distances, which were received in different vessels for that purpose, I found that the same proportion of mercury was received at all distances, equally as in the farthest vessel which received the fluid from the contracted orifice of the tube; thus then there seems to be no dependance upon this application of mechanical knowledge arising from the different weight of the particles under a state of solution.

It follows then, that however different bodies may be in their gravity, in their natural and combined state, from that in which they are when dissolved, yet that they must altogether be considered as a homogenous and uniform fluid, with respect to all the laws of motion and circulation.

If this be true with respect to the weight in the minutest particles in the state of solution, what will become of all that talk concerning the grinding down, and comminuting the particles of matter in a fluid state; is it imagined that the particles of water are
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in the least degree lessened, since the first creation of them by all the friction, which they have undergone in the agitation of the ocean by storms and tempests ?

The union of the red blood globules, each of which is said to consist of six others, show us that similar particles of matter are held together stronger than dissimilar by attraction, but every difference arising in the nature of fluids must arise from some effect produced by different degrees of fire, as the transmutation of the juices of the earth by heat called into a plant, and changed from crude and watery to rich and fermentative, as in the grape ; that is, totally altered in their nature : these again, made vegetables by the action of the heat, are farther transmuted into animal substances by another degree of fire, acting on these substances in the animal vessels.

Thus something must certainly be produced by the action of fire in each of these instances, besides the dividing and subdividing of particles in infinitum : a vegetable divided to all eternity will be but vegetable still not animal substance : without this influence of heat in an animal body, marble is as much marble in its minutest imaginable particle

as in a block as big as the obelisk set up at Rome by Sixtus Quintus ; and all possible combinations of these particles will never offer any idea, but that of marble to the imagination.

What Harvey has said with respect to the atomical philosophy, is undoubtedly true ; in speaking humido primigenio. Cum itaque videam, ex uno hoc humido [tanquam materiâ, aut radice prima] partes omnes fieri & augescere : idemque necessario ita fieri, ratio antedicta suadeat : continere me sane vix possum quin Empedoclis & Hippocratis etiam sectatores [qui corpora omnia similia ex quatuor elementis contrariis ceu mista congregatione generari, & segregatione corrumpi volunt] vellicem ac perstringam : nec minus Democritum, eumque sequentes Epicureos ; qui ex diversarum figurarum atomis, simul congregatis omnia componunt. Quippe olim eorum omnium hodièque etiam vulgaris error est, corpora omnia similia ex diversis sive heterogeneis generari. Hoc pacto enim, Lynceis oculis nihil esset simile unum, idem, & continuum ; sed potius apparens solum unio, minimorumque corporum congregatione vel colliga-

tione quadam, facta congeries & acervus : neque generatio ab aggregatione, debitaque partium positura quicquam differret.

This, and many other passages, in the works of this unstudied and superior genius, strengthen what has been already offered.

Having thus set aside the probability of what has hitherto been said by physiological writers on this head, let us propose what we have to say in the place of it ; and the better to effect the explanation of this phenomenon of secretion, let us recollect that certain different degrees of heat have the power of converting the juices of the earth, by means of such small things as seeds, into trees with leaves, blossoms, fruits of different tastes, odours, and colours, and forming an animal from so small a beginning as the cicatricula in an egg, by converting the white into all the different fluids of red blood, urine, serum, bile, and other secretions : that the heat of 98 has this power is indisputable, it remains then that some account be shewn how they are secured after they are formed.

That it is not as particles of different sizes is very plain, size making no alteration but

in the idea of magnitude, and not in the nature of things ; besides, all the vessels of the body are round, and there is no idea to be gathered from the observations which have been hitherto made, that fluids ever pass the orifices of tubes, in a succession of their minutest particles; this would be to confound the idea of fluidity and dust. Whilst the animal is forming in utero, vel ovo, every part of it is formed in succession one after the other, each gland and the juice necessary for that gland together : as bile in the liver, urine in the kidneys, saliva in the salival glands, and so in other parts of the animal, as in the vegetable, the different kinds of juices.

Now there is, through all nature, a strong and particular attraction of the particles of the same body to one another : this it is which makes oil readily unite one drop with another, water one drop with another ; and this attraction it is, so strongly found in the similar particles of the same fluid, that prevents their union with the dissimilar of another fluid, as that of water with oil : hence, though the dissimilarity of two fluids in this respect, may not be so strongly found again in any two others, yet there
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are other fluids which are slow in mixing, as urine and saliva, bile with urine, and others, in different degrees; which phænomenon in fluids has not yet been attended to with sufficient regard.

There is also this to be constantly found in the pores of any body, that where fluids of particles dissimilar to another have pass'd, there no other will pass till these are totally exhausted; for instance, a paper which has filtered oil through its pores, will suffer nothing but oil to pass it, though you put in oil and water promiscuously after the first time: and the same in the case of water being first put in; nothing but water will pass, without adding some pressure to force them thro': a piece of linen cloth, which conducts a fluid, in the nature of a syphon, if it be impregnated with oil, and then put into a vessel of oil and water, will conduct nothing but oil; and on the contrary, nothing but water, if first impregnated with water, that is, the particles of that fluid which are more strongly attracted by each other than by those of the other fluid, which is blended with it, will follow one another with most ease and readiness through the paper or along the linen rag; and this will

hold good in proportion as the particles of two fluids are more or less similar to each other.

In returning then to the formation of the foetus in utero, the different fluids being formed as the animal encreases, each different fluid as it is generated finds its way through the pores, which are already formed, as in the arteries, through those which are on the sides, and through the glands, as they succeed each other in generation; and this will be the same, whether the gland consist of one protracted tube, or of folliculi or cryptæ.

Thus then these glands, and these pores, having once admitted such and such particular fluids, will no more suffer others of a different nature to pass through, than the paper dipt in oil permits water, or that in water permits oil to pass through its pores.

In like manner, in the circulation of the blood as all these particles are formed by the action of 98 degrees of fire operating on that fluid, whenever they pass by, and come within the sphere of attraction of those fluids already secreted and continually secreting, they unite with them in the pores, like two or more drops of water into one; and thus
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the glands continue to secrete the same fluid as long as the animal continues healthy, and to admit no other; and by this method it seems to be that all the secretions of the animal body are performed, and continued.

However, if, through want of animal heat, proper diet, or infection, the nature of those fluids is changed, then another, the next in similitude, takes place, as in leucophlegmatics, petechial, and miliary fevers.

From this account, some reason may be assigned why some men can never be made fat; that fluid having never been secreted in the infantine state to any great degree, there have been no pores in this body accustomed to let it pass through them sufficient to make any degree of fatness; for this reason in emaciated states, where the fat is exhausted, and a limpid humour of another nature has passed through the pores, where the fat went before, it is extremely difficult to restore the person to his former plumpness; the greater the dissimilarity of the fluids, the more difficultly they take place of each other.

Again, in cases where the bile is returned into the blood, we see that it forces itself

into all the lymphatic arteries, as into those of the white of the eye, and urine not fecerned, passes off through the pores of the skin; because those fluids, though sufficiently dissimilar to the native and natural ones, originally secreted in the glands, so as not readily to unite with them in the circulation; yet, upon being forced back into the blood in an over proportion, they unite and go off along with others, as the urine in perspiration, and the bile in the urine.

There is, besides this, a farther transmutation, effected on the fecerned fluids, after they are in the glands or folliculi, in animals as well as vegetables; and in the formation of all of them, the semen is one of the last.

As to what relates to the structure of the glands, which are called cryptæ or folliculi, the excretory ducts pass off from each of them, between two membranes, as the ureters enter into the bladder; and this mechanism it is, in inflating the tunica cellularis, that hinders the breath from escaping; as it only goes on from one to another, by the ducts of communication, without passing through the excretory duct; and it seems very probable,

bable, that the mechanism is ultimately the same in all the glands, though injections (very uncertain experiments, from whence to draw positive inferences) seem to contradict it.

C H A P. XV.

Of the Pulse.

FROM what has been said, in the preceding part, concerning the motion of the heart and arteries, perhaps some more satisfactory account may be given of the pulse, and the various phænomena which it puts on, in different diseases, than has hitherto been done; this will probably lead physicians to some surer indications to the use of phlebotomy in their practice, or to abstain from it.

Whatever then it may be, in the animal fluids, which can encrease the attraction and degree of the vital fire; or, the attraction continuing the same, can render the discharge less than usual, either of them will at length produce an accumulated degree, which must naturally exert itself on the heart and arteries, in the following manner;

In proportion then, as this heat increases, the diastole and systole of the heart will be augmented, because the greater the quantity of animal fire which is imparted to the heart to a certain degree, the greater will be the diastole; and consequently, the force of the fibres in the contraction being proportioned to the distension, the systole is stronger also. Let the vital heat and quantity of fluids be what it will, the heart must empty its ventricles during each contraction, or cease beating.

In the arteries the same thing will happen in much the same manner: these vessels are not emptied, like the ventricles of the heart, in each pulsation, and the systole or elastic effect of the tube cannot be corresponding to the dilating, because the blood being more in quantity, or more dilated by the vital heat, opposes the contracting power of the arteries, and keeps the sides in a præternatural distension at the times of the systole, as the heat gives it one in the diastole; yet the elastic force of the arterial coats operates stronger in the systole, by its contraction, as the dilating power is greater in the diastole, and this gives a greater momentum to the blood; and as that fluid is dilated by the increased degree

degree of animal heat, which is the same as if its quantity was increased; for all fluids are more or less in measure, as they are hotter or colder; the pulse becomes stronger and quicker; stronger from the increased degree of this vital heat; and quicker, because a greater quantity of fluid must be circulated at the same time with a less.

But this strength of pulse, and velocity of circulation, does not continue to encrease in proportion to the augmented heat; for when the vital fire is advanced to a very great degree, the artery is so far distended by it; and the fluids dilating in like manner from the same cause, it becomes extremely difficult to give it a farther dilatation in the diastole: and thus the circulation is continued with the utmost pain; and in this manner the patient sometimes expires in the first days of the most ardent fevers, the circulation not being continued.

This great distension of the arterial tube, by means of too great a quantity of vital fire, makes that pulse which is called the tense or oppress'd, and is the extreme of all those pulses which attend too great ardency, or arise from too much vital fire.

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It is very manifest, that no state in which an animal can exist, can possibly require bleeding more than this, which has been just mentioned ; and accordingly it will be found, by whoever attends to it, that the pulsation in the arteries of the other arm, will be freer as the blood flows out from the orifice, the obstacles being removed by diminishing the quantity of it, and the vital fire decreasing at the same time by the evacuation, till each comes nearer the state of nature ; and thus the violent dilatation of the artery being lessened, the vibration goes on in a more regular and uniform manner.

Thus the cause of strong pulses, carried to too great a degree, is the cessation of all motion ; and wherever a certainty of this hardness arises from this encreased heat, there bleeding may be indulged with freedom at any time or state of a disorder ; but it must be well decided, whether it springs from too great heat or not ; for without due attention to concomitant symptoms, this seeming hardness alone will lead the physician into very fatal errors. This we shall endeavour to explain hereafter.

Let us now see what will be the effects on the heart and arteries, and consequently on the pulse, when the animal heat is sunk below health; this will be naturally the antithesis of what has already been said in the preceding instance.

In proportion as the vital fire sinks below the standard of health, is the moving power of the heart and arteries decreased, and the blood less in volume: thus then the diastole of the heart and arteries being less at each dilatation than in nature, the systole or the elastic power is less also, and the circulation painfully continued; for this reason as the impulse is small which nature gives in the action of the heart and arteries, it must be more frequently repeated, or the blood would soon stand still, and life be at an end: this, in the different degrees from health downwards, makes the low and quick pulse; and sometimes the slow pulse also in fevers; and as in the ardent state the pulsation may be stopped from too great a quantity, so in this the cessation of that motion arises from too little, and this too, like the former, towards its extreme, is attended with

with a hardness in the artery, that vessel being contracted beyond its natural degree, thro' want of vital heat to dilate it.

This hardness is extremely different, in its cause, from the former, the first feeling hard from distension, the latter from contraction; and this last is what should be called the hard contracted pulse, to distinguish it from the former.

Every ounce of blood drawn in this case advances the danger beyond what is easily to be imagined, and generally proves fatal ; for this reason this hardness is carefully to be distinguished from that in the former case, or inevitable miscarriages must happen in the practice of every physician ; as I have very often seen in the indiscriminate bleedings which the French make use of in their hospitals, where the patient frequently dies under the operation, and seldom outlives the repetitions of it.

From certain degrees of the vital fire, above or below the standard of health, from some irregularity in its being attracted, and dispersed, through the nervous system, arise those pulses which are called intermitting,

ting, as well as the remitting, rebounding or unequal, as they are distinguished by doctor Solano.

An intermitting pulse may arise from too great a degree of vital fire, in this manner : During the pulsation of ten, or more, or less strokes, there may be accumulated a greater degree of fire by attraction, than has been required for the motion of the heart and arteries ; this passing to these parts in a greater degree than before, suspends the stroke during the time of one pulsation, till it is sufficiently discharged, so that the systole can take place by the elasticity of the fibres ; and thus this kind of intermission will happen in proportion to the degree of vital heat which is accumulated in any supposed time, and arises from that cause.

In like manner, an intermitting pulse may take its rise from the quantity of vital heat being below the degree of health, in the following manner, during any number of pulsations, ten for instance : there may not be vital fire enough either attracted or distributed, to overcome the resistance in the elastic fibres of the heart and arteries, for more than nine pulsations, and, of consequence,
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there follows a cessation of motion at the time of the tenth, till a degree of vital heat is attracted, to be supplied to those particular parts; besides this, there are effluvia which are generated in some stomachs, in particular indispositions, which repel the vital heat, as shall be explain'd when we come to speak of the causes of disorders; and those also cause a cessation of the pulsation, in particular diseases and habits.

It is this last kind of intermitting pulse which takes its rise from too small a degree of vital heat, that most frequently occurs in practice.

The *pulsus dicrotus*, or rebounding pulse, observed by Dr. Solano, where the pulsation is stronger at certain distances, such as the thirtieth, sixteenth, eighth, fourth, &c. is referable to the same cause with the intermitting pulse, which arises from too great a degree of vital fire, accumulated during the time of a certain number of pulsations; but as in the intermitting pulse, from this cause, the vital fire is accumulated to such a degree, that it suspends the systole or contraction of the artery; so in this, it is only increased enough to make the vibration greater than

than at the others ; and thus this pulse, when it happens, is of that kind which arise from too much vital fire; and therefore, when the cause of it is known, it would be wrong to delay bleeding, in expectation of a critical discharge by blood from the nose, at the distance of two, three, or four days, when a lancet can effectually procure the same advantage.

The intermitting pulse has been already ascribed to two different causes, too much, or too little quantity of vital fire ; if that be the truth of the case, it seems something difficult to assign how a critical discharge by vomiting and stool, or by urine, should be the consequence of causes so different in themselves, as those which produce an intermitting pulse ; but probably the latter kind happening twenty times, or ten times that number for one of the other, it may be consider'd as universally arising from this cause, the too small degree of vital heat.

The unequal pulse, which rises in height and vigour above the other diastoles, requires some degree of attention and accuracy, to distinguish whether the pulsation, which is more vigorous than the rest, is above the
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common force of nature, during the health of the sick person, or whether the others are below it ; this demands some care in the decision, for bleeding may be safely prescribed where the stroke which exceeds the others in force, is caused by a too great degree of vital heat ; but it must not be permitted where all the other pulsations are below the natural force of the patient, and that of the greatest vigour only rises to the degree of the healthy pulse.

Thus, it seems pretty plain, that all those kinds of pulses just mention'd, take their rise from the different degrees of vital heat, which are above or below the standard of health ; the great concern of every physician then is, to distinguish, where the symptoms appearing to be much the same, as in the hardness of the concentrated and oppressed pulse, or in the intermitting of each kind, and the unequal, from which excess of the two degrees of vital heat they spring.

In order to decide this with the greater certainty, and to avoid bleeding whenever it is improper, and which, tho' not immediately fatal, is ever either beneficial or pernicious to some degree ; it will be necessary to observe

serve with all possible care, the symptoms which accompany these different kinds of pulses, arising from a degree of vital heat, either above or below that of health: without strict attention to these, we may be deceived in the feeling, nothing being more various than pulses in healthy people.

In the oppress'd pulse, the artery will seem full, the coats distended, as it were, and the fluid nearer your fingers; the veins of the hands will be swoln in like manner, a heat greater than that of health over the whole body, a hotter breath than usual, attended with difficulty and quickness of breathing, the lungs and thorax distended, the air being suddenly rarified from the great heat in the chest, inflamed eyes, and redness of the countenance and skin, not like that which is called a flushing in the cheeks, but a general glowing over the whole face, neck, breast and body, a delirium, and the urine very hot, when it is voided from the sick person.

When these symptoms, more or less, are perceiv'd to accompany the pulse which seems oppress'd, bleeding may be indulged to the great benefit of the sick, and one evacuation

taken suddenly from a large orifice, which brings on a syncope, will be of more efficacy in removing those symptoms which accompany an ardent fever in the beginning of it, than several repeated operations of that kind, where fainting does not succeed, and where there is but little alteration made in the heat of the fluids, and the body from whence it is drawn.

My reason for saying this, with respect to the advantage which results from fainting, is this, that it has been my constant observation, that wherever this fainting succeeds phlebotomy in ardent fevers, that there the heat is never so great after it as it was before; and very often the disorder terminates with a profuse sweat immediately after the syncope: this a quick discharge of blood from a large orifice, tho' the quantity be less than what you draw from a smaller aperture, will effect, as may be known from hæmorrhages of the smaller arteries, where three times that quantity of blood is lost which is taken off in bleeding without fainting; the reason of this shall be explain'd when we come to treat of ardent fevers.

In the concentrated pulse, the following symptoms are more or less concomitant : a great dejection of mind, sometimes as if the soul or animating principle had deserted the body, a heaviness or swimming in the head, or a vague kind of delirium, something between sense and nonsense, of a different kind from that which attends the oppress'd pulse ; an oppressive breathing, where the chest is not sufficiently dilated, a languor, paleness, dispiritedness, and sometimes lividness in the countenance, a glassiness in the eyes, restlessness, no sleep, tho' seeming drowsy, heat in particular parts of the body, and cold in others ; and tho' the hands may appear hot, and sometimes a flushing in the face, yet these symptoms are not to be taken as signs of great heat ; generally at this time there is some degree of cold, greater or less, complain'd of in some part or another ; and if you compute the heat from that of all the parts external and internal taken together, (for wherever the patient complains of a sense of cold, there is cold, tho' the skin may feel warm externally) it will be found below the standard of health. Nothing has done more mischief in the art of healing,

than this, of imagining that an animate body, like a piece of iron, is under the same laws of being heated; or because the hands or feet are warm, that the whole body must be so likewise! this experience shows the contrary of; and therefore a thermometer, tho' it can tell the true heat of a person in health, where the vital fire is equally dispersed thro' the body, yet it cannot decide of that degree which is in disorders, where the vital heat being unequally distributed thro' the nerves, makes a greater degree of ardour in one part than another: the manner in which this is effectuated, we shall endeavour to explain hereafter.

In this case, and with those symptoms, it would be more or less destructive to bleed, since the patient being already below the degree of 98, every diminution of the blood will continue to decrease the vital heat; and thus gangrenes and mortifications succeed in those internal parts, where a sense of cold has been complained of, as in the intestines, at the close of slow and putrid fevers.

There is a symptom which often accompanies those already laid down, and which may be apt to mislead those physicians, who
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have not observed with much care the others, which are inseparable from it in some degree ; this is a great throbbing of the carotid and temporal artery ; when the sick is almost exhausted, this symptom, from a difficulty hitherto insurmountable, in assigning its cause, and imagining upon the old system of the circulation, that the projectile force of the heart was the cause of this throbbing, has led many a physician into bleeding his patient, and thus hastening the end of that life which was before in too much danger.

This, however strange it may seem, is no indication of a stronger power acting on the blood ; but it arises from an unequal distribution of the vital fire to particular parts, and is an infallible sign of its deficiency in others ; and farther, it appears to be almost a demonstration, that the diastole of the arteries must arise from some cause totally distinct from that of the projectile force of the heart, acting on the blood in circulation.

This kind of throbbing pulse is ever much to be suspected, even in the arteries of the arm, and is frequently deceitful, the physician being led to consider it as arising from an universal plethoric disposition of the fluids ;

whereas it sometimes takes its rise like that in the temporal and carotid artery, from an unequal distribution of the vital fire; and wherever this throbbing pulse is found, the symptoms which accompany it should have the strictest regard paid to them, to decide to which cause it belongs, whether from too much vital fire universally spread thro' the whole animal frame, or a partial disposition of it to particular parts; the first of these demands bleeding, and the latter absolutely forbids it.

In both kinds of pulses, either from an excess of vital heat, or a decrease of it, the extremes of each are seldom met with, the intermediate degrees very commonly, and in each case the pulsations are accelerated; but the symptoms already described, must be taken into the consideration before bleeding is prescribed; as you approach towards the extreme of decreasing heat, it frequently happens, that the deficiency of vital fire makes the strokes more distant from each other than they are in health, and even in fevers of the worst kind, which rise from infected juices and nervous indispositions, which lessen the vital heat.

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And tho' it has been first said by Dr. Boerhaave, and afterwards by Van Swieten, that the pulse of all people sick in fevers, is quicker than it is in nature; I must take the liberty to affirm the contrary, from repeated experiments; and even in the ardent state, I have more than once felt the pulse slower than nature, from too much vital heat distending the artery, and keeping it so, longer than it does in perfect health.

The little wavering pulse, the low continued trembling and fluttering pulse, are all to be ascribed to different degrees of the vital heat less than that of health; and consequently forbid the lessening the crassamentum of the blood by phlebotomy, which lessens the power of continuing the vital heat; nor can it ever be permitted, without more or less danger to the patient, and never with any good effect.

There is another kind of pulse: when the artery feels hard and stiff like a large wire, I have imagined that this arises from a kind of inflammation of the arterial coats; perhaps the fluid in the cellular tunic does not pass off with so much ease as it does in times of perfect health; and thence this sen-

sation of hardness and stiffness is communicated to the touch: in this instance, the symptoms which accompany a degree of vital heat superior to that of health, are generally to be found; and therefore bleeding may be prescrib'd.

But, in case of doubt, the physician should attend and examine the artery in the other arm, which if it beats with more ease, and seems softer as the blood flows out, it is apparent that bleeding will be serviceable; if, on the contrary, the pulse becomes increased in stiffness and hardness, the blood must be immediately stopt: in this case the orifice should not be made so large as in the bleedings in ardent fevers, lest, by too great a quantity of the blood passing off very suddenly, the physician should not have time to distinguish in the artery of the other arm, the differences which arise from the lessen'd quantity of blood.

There are, besides the pulses which have been mention'd in this chapter, many others which are only nominally different from those already described, to be found in medical writers; but as they are all referable to the causes already assign'd, it would be useless

less to pretend to a particular description of each of them ; too much precision in describing the effects, where the causes are the same, is puzzling and indecisive in the minds of all good reasoners ; no instances are perfectly alike ; there must be allow'd a certain latitude in the general, and this best answers the utility which is to be drawn from observation.

What has been hitherto said on pulses, is only done with intent to decide with some greater certainty than has hitherto been known, when bleeding may, and when it may not be permitted, abstracted from all particular diseases whatever, and from all causes which increase or lessen the vital principle. When we come to speak of the disorders in which those different pulses make part of the symptoms, we shall endeavour to explain, in assigning the cause of diseases, whence it arrives, that the animal heat is augmented in some, and diminish'd in others.

What we have done was intended to range the various pulses and their phænomena, under the different heads to which they belong, to give some clearer idea of what has been meant by the above denominations, in
physical

physical writers of the best authority, and to find a philosophy which may explain the manner in which the facts that passed before their knowledge were produc'd.

This was done to afford greater safety to the patient, and impart a greater satisfaction to the physician ; for nothing can be a more pleasing consideration to a humane practitioner, than the seeing the theory of his profession confirmed by the result of his practice, and that observation and experience unite to confirm the truth of what he had laid down as the first principles in the medical art ; this will preserve him from that fluctuating indecisive proceeding, which not being continued long enough to do good, thro' want of a satisfactory knowledge of principles, is eternally doing mischief, by incessant changing, and has hitherto been the disgrace of physical science.

C H A P. XVI.

Of I D E A S.

IT may be thought by many people, that the following chapter concerning ideas has no kind of connexion with the other parts of this essay; and that a subject which has hitherto been considered as metaphysical, should not be mixed with that which is entirely physical.

But if it be considered a little closer, that delirium is no more than confusion of idea; and that it is a symptom which makes part of those which attend fevers, and not that which demands the least attention; it may be considered as belonging to the subject we are treating of, especially since it may lead to explain, in some degree, the cause of madness also.

Another reason for its finding a place here is, that the manner in which voluntary and involuntary motion has been explained, if it be attended with truth, having set aside the former accounts by means of animal spirits, æther, and vibration of the nerve; it becomes
 necessary

necessary to put something in their place, and shew how the method which we have adopted, will answer in the explanation of ideas; without this, after all the pains which we have taken, there remains an objection against this manner of explaining things. If the former manner of accounting for ideas, by animal spirits, æther, or vibration of the nerve, be still necessary, to what purpose have we assigned a new cause of vital heat and motion, which is imperfect in this part; whereas the old way affords a kind of solution of all these difficulties, and of ideas also? To have raised a new system equally open to difficulties with those already known, is but to place one imperfection in the room of another, with nothing to recommend it but novelty, which, supposing that it should find present favour in the eyes of physiologists and physicians, is only like the buildings of those skilful undertakers of houses on a lease, that fall of themselves, at the expiration of the term.

Before I endeavour to establish any thing relating to ideas, from the manner and principles which have been already used to explain vital heat and motion; I shall endeavour

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vour to prove that every account hitherto given, must be erroneous, even allowing the authors of them all they require.

Let us begin with supposing, that there are such things really existing as animal spirits ; and then examine whether, in the manner which has been hitherto pursued, they can be made to account for ideas, and their vast variety ?

This fluid has been always considered as something homogeneous in its particles, and consequently the whole variation which it is capable of, is more or less with respect to quantity ; or moving swifter or slower with respect to that quality ; and in like manner, if you adopt the system of æther, the same can only be said of it, that it is more or less in quantity, or has more or less velocity : thus, whatever arguments can destroy one of these accounts, will effectually destroy the other.

That different quantities of the same thing cannot create any idea but that of quantity, is pretty manifest : this ink before me is black, in the small part of it called a drop ; it is black also in the whole standish, in a larger quantity ; and so on, to whatever quantity you please ;

please : there is no change of ideas here, but in that of quantity, it is more in one place than another ; but the ideas of black and fluidity remain the same in all instances, and consequently more or less in quantity of ink cannot alter the ideas of quality, and more or less animal spirits can be only considered as something of the same nature in a greater or lesser quantity. This will be farther explained immediately, in considering the effects of different degrees of velocity, as causing the variety of our ideas.

Let us now consider the animal spirits or æther, under the notion of motion ; and see what will be the result of that manner of examination : the whole variation, which these fluids can receive, in their motion, is that of quicker or slower, or striking the mind with stronger or weaker impressions ; the ideas of quicker are slower, are always relative to matter in motion, distinct and separate from the moving body : we say, one horse, or one billiard-ball, moves quicker or slower than another, one musician plays quicker than another ; and thus, in every instance, slower or quicker are ideas relative to every thing in motion, and cannot possibly create
any

any other idea but that of motion in different degrees. If you take the idea of an impulse making stronger or weaker impressions, that comes all to the same determination, nothing being distinctly created there by but the ideas of stronger or weaker ; a stick strikes stronger or weaker, a billiard ball strikes stronger or weaker : in all these considerations, no idea can be created but the different force of the ictus of percussio, the idea of the billiard-ball or stick, being the same in every degree of velocity or force, and that relative idea of motion only varied ; and in fact, with respect to the nervous fluid, stronger and weaker, quicker and slower, seem to be much the same idea, that which strikes strongest moving quickest, and so in the inverse.

But let us allow all the possible degrees, which any thing put in motion is capable of receiving ; it can be no more than indefinite, because whatever has a beginning cannot be infinite ; but if the idea of infinite be more agreeable, take that, it will make no alteration in the argument.

Let us, to explain the effects of this increase of motion in the fluid called animal

spirits on our minds, take some one colour, and run a parallel between them, and then see what will be the event of such an examination. Let the colour be blue, for example :

The first imaginable motion in this fluid, corresponds exactly to the first imaginable tint in the colour blue ; for conceive the motion as small as possible, the shade of the colour can be imagined equally slight also : thus then, beginning with the first possible degree of motion in the animal spirits, all the consequent degrees, however nicely divided by the imagination, cannot exceed all the possible shades, which can be conceived in the colour ; thus the first possible motion expressing the first possible tint ; and then all degrees of motion creating all degrees of the colour blue, the whole sum of the motion is equal to the whole colour of blue in all its shades : the first and last motion in the animal spirits answering to the first and last shade in the colour : and thus every motion in the animal spirits must create a new shade in the colour, by its alteration ; and consequently, all possible conception of motion in all its degrees being exhausted

hausted upon all possible shades of one colour, blue, there remains no manner to account for the infinite variety of our other ideas in nature, in proceeding to explain them by this method. Thus the animal spirits or æther can answer to nothing but a series of degrees under one general idea, as all the shades of blue under the abstract idea of blue; and all possible application of them is at an end, there being no more than infinite degrees in any thing; and if you allow the motion infinite in the fluid, you must allow the degrees infinite in the colour; and thus the whole possible idea of various degrees of force in motion, as creating different ideas, is totally exhausted in the various shades of one colour.

By this means we are totally at a loss to explain the cause of all our other ideas. In truth, nature, simple as she is, is not so simple as some philosophers have conceived her to be; no one property in nature has a right to, or possibly can, explain another. In fact, colour is colour, and motion is motion, and not one the cause of the other, in any sense; each stands upon its own basis, and relative to the senses which perceive them; and it would be equally true, to begin by asserting, that the

different shades of blue communicate all the different degrees of motion, as those of motion communicate colour.

If vibration of the nerves be placed in the room of animal spirits or æther, we have no more than the two ideas above, of stronger and weaker, quicker and slower, which, in the vibration of a string, is one and the same thing, according to the laws of vibration in other strings; and thus, what could not be true, in the former instances of animal spirits and æther, cannot be true in the case of vibration; or, in allowing velocity and force to be two different ideas, there is but one feeble assistance added to the account, which, being pushed to infinity, and combined with the other, makes but some third idea in all possible degrees; as for instance, let the second quality, force, be yellow, and then combine it with blue, in all possible degrees of each colour, and you have no more than one general idea of green, including all possible shades of that colour; and thus, at last, in allowing every thing, the whole source of accounting for ideas is totally exhausted upon the principles of animal spirits, æther, and vibration of the nerve, in communicating the ideas of two colours in all their degrees of shade.

There

There is, besides what has been already said, another objection to the accounting for ideas by means of animal spirits, æther, and vibration. There is no direct communication between the object and the sense; it is only that of a relation to a relation, that is, the rays of light, for instance, stand in a certain relation to the animal spirits, and these in another to the mind; or, which is the same thing, the particles of light communicate motion to the animal spirits; these, running along the nerve, impart this motion to the sensorium, which, to an unphilosophical mind, does not appear to be the true manner which nature has adopted. It is a prolixity which adds no advantage, and after all possible explication, terminates in nothing but motion; the same difficulty arising in this manner of accounting for ideas, to whatever sense you apply it, and though to two differently formed senses, such as hearing and seeing, that which created the idea of colour to the eye, may be sound to the ear; yet the variety of ideas belonging to any one sense, can never be owing to motion in animal spirits, æther, or vibration of the nerve.

Let us now try, whether the same matter which has been assigned as the cause of vital heat and vital motion, may not be the cause of ideas : this we have already said was nothing more than fire. We have one circumstance very favourable to this manner of considering ideas, which is, that heat, motion, and ideas, are always together in the same subject which thinks ; and that when the two first desert the animal machine, the other always accompanies them.

To explain what we would be understood to mean, by fire being the cause of ideas, let us take that element, as it appears to one of the senses, under the idea of light ; it has been already sufficiently proved, that fire and the electrical effluvia are one and the same thing ; that the nerves conduct this fire to all parts of the body ; and that, in every degree of distance in which it has been tried, it moves instantaneously ; thus then, it being manifest that this element passes by the nerves momentarily in all electrical experiments, what need have we to have recourse to animal spirits, æther, or vibration ?

It has been hitherto said, to explain vision, that the light passing through the humours
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of the eyes, forms a focus of the rays on the retina ; and then the animal spirits running back to the sensorium, inform the soul with what was passing in the eye ; and thus the mind is acquainted with light, colours, and other objects of vision. We have already shewn how it was impossible, that ideas could arise that way ; and indeed, what need is there of animal spirits, since the very particles of light may pass themselves to the sensorium, and communicate the idea of themselves ? This is analogous to what we experience in experiments of the electrical machine, where fire is instantaneously carried through the whole body by the nerves. In this way, there is no occasion for explaining things otherwise than they are conceived in nature ; the very thing seen is in the place where it is beheld, that is, a constant succession of rays from the object, is present in the sensorium.

That fire is a species of matter sufficiently subtle and fine for this use, there will be, I imagine, but little reason to doubt, when its velocity, and passing through such minute pores, are taken into consideration.

By this manner of imagining, that the objects of light are communicated to the mind, the prolixity and absurdity of one relation to another, of a communication of motion from light to animal spirits, æther, or nerves, and then to the sensorium, is totally avoided; and the absurdity of different degrees of motion being other than different motion, is no longer necessary to support a falsehood which would never have been credited, if it had not been considered as something above the common apprehension, and preserved in the word philosophy, as flies are from corruption in amber.

One very considerable proof of the truth of fire being absolutely the cause of ideas, is this, that in electrical experiments it has communicated ideas to almost every sense; it is light to the eye, odour to the nose; stroke to the touch, sound to the hearing; to the taste it has not yet been applied.

Had that great man, Sir Isaac Newton, considered fire in this manner, it is not easy to conceive to what degree of explanation and discovery he would have carried the thought, by so just and vigorous an imagination as he possess'd.

Perhaps

Perhaps something may be brought to strengthen this way of thinking, from the great analogy there is between the properties of sound and light.

In light, that which forms the idea of white, is known to be compounded of seven different colours intimately blended together; there can be no more original tints discovered by any experiments hitherto made; and all the million of colours are compounded from these seven. This very number is capable of great changes, as multiplication will tell us; but when we come to add, that each of these colours may be mixed with the others in infinite proportions, there arises a ground for all the variety of ideas, from some change in the substance which creates them, and not from different motions.

The same holds equally true in sound; the original sounds are seven, and no power has hitherto been able to create a new one; their combinations and divisions answer exactly like the seven tints in light: harmony and discord are no more applicable to music than colours, each are equally obedient to the same laws.

To explain this difference which is in nature, to the different senses, every idea of our senses may be created two different ways; that is, the causes of the ideas which belong to vision, hearing, tasting, smelling, and feeling, may be all different from one another; or all these may be the same to every sense, and the senses differently formed.

In the first way of considering things, the cause of sound is totally different from that of vision, and so on through all the senses: this creates an infinite variety not only in the objects of each individual sense, but every sense has its infinite variety, as separate and distinct beings; those of smell from those of taste, &c.

But if you suppose the senses different, which they certainly are, then there arises the same variety from one species of being, such as those of colours, to senses differently formed, that there does to the senses from all the objects being different.

This seems to be the plan which nature generally proceeds upon, and embraces within itself the idea of uniformity and variety. It is more uniform to suppose but five senses
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differently formed, and the objects the same, only as they are offered to a different sense, than to suppose each sense different, and the objects of the five totally different from each other also : in the first way, five differences in the senses makes that variety which is the object of one of them, the object of all ; and in the other the variety arises from the infinite variety of all the objects, without respect to the particular sense to which they belong.

Let us then imagine that the difference in objects arises intirely from the different formation of our senses ; that the ear is not formed like the eye, nor the touch like the smell, is manifestly true ; and that all the different objects of these senses are one and the same ; that is, those of vision the same with those of sound, and so on ; thus then, the particles of fire or light, which are seven distinct colours to the sight, out of which all other colours are made, may, to a sense differently formed, as the ear, be seven distinct sounds, or seven distinct tastes to the palate, and so to the other senses, out of which all the variety of nature is formed ; and thus from one variety of nature, to one sense,

sense, which is infinite, arises five different varieties to five senses differently formed ; and in this way is avoided that contradiction of five infinities, which is an absurdity to every one who attends to this manner of considering things.

It is probable that the colours of all bodies arise from the different attraction and repulsion of the rays of light, which fall on that body ; thus an object which appears blue in all probability absorbs all the rays of light but those which are blue, and reflects them ; and thus the object appears blue, those rays being only reflected to the sensorium : in like manner, those rays of light or fire existing in every body, it may not be improbable, that when elastic bodies are struck, that order of particles, supposing violet for example, which is least attracted, is shaken off, and propelling the same kind of particles, which it is attracted by in the air, which is also an electric per se, it at last arrives at the ear, where the structure being different from that of the eye, that which was a blue colour to the sense of seeing, may be the note F, or any other, to the sense of hearing.

It is probable also, that the difference of the velocity of sound to that of sight, arises from the necessity of air being employ'd in the continuing the particles to the organ of hearing, or rather from the fabric of the ear itself; for wherever there is a communication of one thing to another, time must be lost.

It is probable then, that those particles which are shaken off from sounding bodies acting upon those that are similar in the air, lose part of their velocity; and even when they do arrive to the organ, there is some reason to believe, that the fabric of it is made to answer to the different particles shaken off, as in the instance of fiddles tuned in unison, where the strings of those which are not play'd on, answer to the corresponding strings and notes of those that are.

In like manner, the spiral lamina in the cochlea, being compounded of fibres of various lengths and sizes, each receives the particles shaken off from bodies, which answer in unison to these strings or fibres in the spiral lamina, whether from metalline substances or cords extended on musical instruments; and the motions in the fibres of the spiral lamina, shake off the same kind of particles

particles which creates A or B, and thence they pass by the nerves to the sensorium; and it is not improbable, that all the different organization of the ear was originally design'd to put those fibres of the spiral lamina in due tension, and in tune; and from the different degrees of perfection in the formation of this organ, arises the different accuracy which one ear has above another, in distinguishing the concord of different musical instruments on strings of the same instrument.

It is probable also, that as musical notes arise from different degrees of tension of the same string, or from strings of different sizes, that each note requires a certain tension, or certain size of string, under a certain degree of tension, to shake off those particles which answer to the note A. B. and so on; and that each of the seven original particles which create the idea of different notes, demands a certain degree of motion to be thrown off from the corresponding strings, and to form those notes which answer to B, C, D, &c. and from this distinct force and tension of strings it arises, that those particles which create B. in the instrument which is play'd
on,

on, being attracted by the similar particles in the string of the instrument which is not play'd on, it is that unison and its effects may be accounted for.

That different degrees of strength are required to shake off different notes, or the particles which create them, may be learnt from the progress of three notes which follow one another in the sound of one vibrating string, or a stroke on a bell, where a good ear can separately distinguish them, as the sound is diminishing in its degrees, and even some affirm, to have heard the whole seven.

Thus it may seem reasonable, that all the difference of objects arises from the difference in the formation of the senses, and that what appears blue to the eye, may be the note A. to the ear, sweet to the taste, fragrant to the smell, and soft to the touch, or whatever ideas you please ; that air, tho' concern'd in propagating sound, is not sound itself, is plain from sound running almost as fast against the wind as with it.

In this manner of accounting for ideas, the objects are directly communicated to the sensorium ; and the manner in which nature

ture conceives them, without having recourse to frivolous and visionary philosophy: the nerve is only supposed to exist, which no one can deny; and to conduct this vital principle, which is the cause of ideas, heat, and motion, in the manner we know it conducts the same being, in the experiments of electricity.

In this manner of explaining things, the same matter convey'd thro' different senses becomes sound, colour, taste, touch, and odour; and perhaps this may explain many difficulties hitherto envelop'd in much obscurity, particularly the association of ideas, memory, and many other things: however, tho' this may account for ideas, we don't presume to advance, that those ideas are the soul itself, and incline to materialism in this account. It appears absolutely necessary, from this manner of explaining things, that there must be some superior part of the human composition, which has the power of combining, separating, comparing, and many other faculties of treating those ideas in the sensorium or particular parts, in which they are lodged.

By means of this, many difficulties in mental nature may receive an explanation hitherto unimagin'd : an idea becomes a reality in this account, a material existence, and the basis of all objects, as they are communicated to the mind, being one and the same, tho' diversify'd by the senses. It may afford some more probable method of explaining the properties of the mind ; but to treat this subject at full length, in all its parts, would require more time than can be allow'd in an essay of this nature of which I am writing.

A delirium, in fevers, seems to arise from two very different causes ; either from the patient's having too much vital fire, which, being the same as the matter of ideas, will, when the brain receives a greater proportion than naturally belongs to it, create a confusion and precipitation of ideas ; for that ideas can move faster or slower, is as certain as that matter can move in that manner ; and this every one must have observed who has remark'd what passes in his own mind, in danger, in fear, joy, expectation, and many other situations of the mind ; thus then, when the matter of which ideas
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are form'd, is in too great quantity, and in a greater proportion than each part destin'd to receive it can contain, there must naturally happen confusion and precipitation of ideas ; there is a greater quantity than the soul can dispose into regularity ; and thus this species of delirium springs from too great quantity of vital fire, or what is called inflammation of the brain, and is accompanied with great ardour, as in the caufus, beginning of the small-pox, and other disorders which are attended with ardent states.

In like manner, whatever can lessen the vital fire, or drive it from the brain, will cause a delirium of quite another kind ; in this instance, the matter of which ideas is form'd, is not in quantity sufficient to furnish any one continued connexion of thought ; there arises a vague and whifling manner of talking, attended with dejection and want of vital force, a general oppression of all the faculties, and universal languor thro' the whole body.

This then as plainly follows from the deficiency of vital fire, as the other does from redundancy ; it is this delirium which attends putrid, and what are called nervous fevers,

vers, and the last days of consumptions, scurvy, and many other chronic diseases which arise from inanition, universal change of the fluids, or from wasting.

It will plainly enough appear, that those two deliriums take their rise from very different causes, and demand a very different treatment; in the first instance, bleeding is always attended with success, and in the latter with infinite danger; and this I am convinc'd of from experiments which were daily made, and which I have seen in the hospitals of Paris, where fevers of the petechial, putrid and nervous kind, are treated in that manner, and which treatment is almost certain death, every bleeding constantly increasing the delirium in diseases of the above kinds.

There cannot then be a more necessary caution, than to distinguish from what cause the delirium arises in any disorder, whether from the increased or diminish'd quantity of vital heat; for as a physician shall distinguish will his success be in practice; and this is for ever true, that it is ten times easier to lower a patient in an ardent fever, who is much above the degree of 98 or of health, than it is to re-

store a patient who is fallen below the degree of a healthy state; and thence of consequence, the danger of ill success in bleeding in those cases is proportionably augmented.

When we come to speak of ardent, putrid and nervous fevers, and to assign the causes of each of them, we shall endeavour to explain why the vital heat is increased in the first, and how it is diminish'd in the latter of these disorders, when it will more manifestly appear, how destructive the indulging the operation of bleeding is in all kinds of diseases, attended with a putrid or dissolved state of the blood, where the animal heat is fallen below the standard of health.

The END of the FIRST VOLUME.



